THREE STUDIES ON FINANCIAL INNOVATION AND DIGITAL ECONOMY

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PhD

The Hong Kong Polytechnic University

2023

The Hong Kong Polytechnic University

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Three studies on financial innovation and digital economy

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A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy

April 2023

CERTIFICATE OF ORIGINALITY

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______________________________ (Signed)

WANG ZIYI (Name of student)

Abstract

My research centers on the topic of financial innovation and digital economy, which can be classified into two main areas of focus: empirical analysis of financial innovation and theoretical analysis of digital economy. In terms of empirical analysis, I delve into the influence of financial product innovation, such as Credit Default Swap (CDS), on the investment in information technology by target companies, as seen in Study 1. Regarding the theoretical analysis of digital economy, I present two studies focusing on the strategies of IT service providers. The first study (Study 2) examines the distribution strategy of a cloud-computing service provider, where I explore the optimal distribution strategy of a software as a service (SaaS) enterprise under both centralized and decentralized channels. The second study (Study 3) scrutinizes the competition and cooperation strategies of two-sided e-commerce platforms in a vertically differentiated market.

In Study 1, my examination focuses on the causal effect of CDS on IT investment. CDS contracts are actively traded in the financial market to mitigate credit risk and are considered one of the most significant financial inventions of the past 20 years. I empirically investigate the causal relationship between CDS and firm-level IT investments, using a US market sample. Through my research, I discover that the initiation of CDS trading can significantly reduce IT investment in the underlying firms, and the decrease mainly stems from software expenditure rather than hardware. Additionally, further analysis reveals that CDS trading decreases IT investment by impacting the credit risk of firms. This effect is particularly notable for firms that heavily rely on debt for financing, belong to high-tech industry sectors, and have stable earnings. This research lies at the intersection of finance and information systems research. The study's findings can be directly applicable to the ongoing policy debate surrounding CDS and have implications for the relationship between financial innovations and IT.

In Study 2, my analysis focuses on the optimal distribution strategy of a Software as a Service (SaaS) enterprise under centralized and decentralized channels. SaaS is a subscription-based web-based software delivery model centrally managed by a provider. Nowadays, SaaS giants tend to diversify their products and distribution modes. I examine the supply chain structure of a monopoly firm that provides both low-end and high-end SaaS. Low-end SaaS is standard and can be subscribed to directly online. High-end SaaS includes customized services, which require communication with customers and should be provided by an internal/external unit. For high-end SaaS distribution, SaaS firms typically choose between a retailing division mode and an external reseller mode. This study explores and compares the two distribution modes of a monopoly SaaS provider. Through analytical work, I reveal that several factors, including the external reseller's marketing advantage and customization cost, significantly impact the SaaS firm's choice of the two distribution modes. The firm tend to adopt the retailing division mode in high-end SaaS distribution when the customization cost is high, or when customization cost is low and the external reseller's marketing advantage is small. I further study the impact of network effect by numerical analysis. I observe that, when the external retailer's marketing advantage is large, the network effect has an increasing positive impact on the profit of the retailing division mode first and then has an increasing negative impact. When the external retailer's marketing advantage is small, the network effect always has an increasing negative impact on the profit of the external reseller mode.

In Study 3, my investigation centers on the competition and cooperation strategies of two-sided e-commerce platforms in a vertically differentiated market. Recently, e-commerce giants, including Amazon, have started linking products sold by their competitors on their platforms, which has been labeled "co-opetition," a combination of cooperation and competition. I examine this strategy by creating a theoretical model within the e-commerce platform context. The model comprises one small and one large co-opetiting firm, each with its online sales platform and market, where vertically differentiated quality products are sold. Three types of cooperation strategies are analyzed, including one-way cooperation, two-way cooperation, and non-cooperation. Product quality differentiation emerges as a significant factor that drives cooperation decision making. Compared to non-cooperation, two-way cooperation results in higher profit margins for both firms when the quality differentiation between the firms is high. Finally, the current one-way cooperation prevents the small firm from paying a listing fee to the large firm, making it unlikely to occur under the co-opetition setting.

To sum up, study 1 focuses on the impact of financial innovation, specifically Credit Default Swap (CDS), on the IT investments of target companies. Study 2 analyzes the optimal distribution strategy of a Software as a Service (SaaS) enterprise in a digital economy context. Finally, study 3 investigates the competition and cooperation strategies of two-sided e-commerce platforms in a vertically differentiated market. All three studies examine different aspects of financial innovation and digital economy, and each provides insights into how companies can leverage these innovations to improve their bottom lines. The findings from these studies demonstrate how digital innovation, particularly within the financial sector, is having a significant impact on various industries, such as IT, SaaS, and e-commerce, and how companies can adapt to these changes to improve their competitive advantage.

Keywords: *financial innovations, credit default swaps, IT investment, credit risk, software as a service, supply chain structure, vertically differentiated market, co-opetition, two-sided platform, e-commerce*

Acknowledgement

The research in this thesis would have taken far longer to complete without the encouragement from many others. It is a delight to acknowledge those who have supported me over the last three years.

I would like to express my very great appreciation to my chief supervisor, Prof. Xin Xu, and co-supervisors, Prof. Jimmy Yong Jin and Prof. Baozhuang Niu, for giving me the precious opportunity to conduct research and providing me with their patient guidance, enthusiastic encouragement and useful critiques of this research work. It was my greatest honor and privilege to study and work under their supervision.

I am particularly grateful for the assistance given by Dr. Ruiqi Liu and Dr. Yaoqi Liu. They have taught me the fundamental methodology to carry out analytical modeling and empirical research and to present this research work as clearly as possible. I am extremely grateful for what they have offered me. I would also like to thank them for their friendship, empathy, and sense of humor.

I would like to express my special appreciations to my parents for their love and support. They are always there for me. Without them I would never have enjoyed so many opportunities. This thesis and all my futuristic achievements should be dedicated to them.

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Chapter 1

Do Financial Innovations Affect IT Investment? — An Examination of the Impact of Credit Default Swap on Firms' IT investment

Abstract

CDS contracts have been actively traded in the financial market to hedge credit risk. CDS is regarded as one of the most significant financial inventions in the past 20 years. I empirically examine the causal relationship between CDS and firm-level IT investments using a US market sample. I find that the initiation of CDS trading can significantly decrease underlying firms' IT investment, and the decrease mainly comes from software instead of hardware expenditure. Further analysis shows that CDS trading decreases firms' IT investment by affecting their credit risk. The influence of CDS on IT investment is particularly pronounced for firms that heavily rely on debt for financing, belong to the high-tech industry sectors, and have stable earnings. This research is at the intersection of finance and information systems research. The findings can directly apply to the ongoing policy debate regarding CDS and have implications for the linkage between financial innovations and IT.

Keywords: *financial innovations, credit default swaps, IT investment, credit risk*

1.1 Introduction

Credit default swap (CDS) has been one of the most important financial innovations in the past two decades. It is a fixed-income derivative instrument where CDS buyers pay sellers a periodic premium (also known as the CDS spread) in return for payment when credit events involving the underlying assets occur (see Figure 1 below; also see Appendix A for a detailed description of how CDS works). In the late 1990s, the CDS market began as a pure insurance market, where bondholders hedged credit risks by buying CDS. Later, other market participants realized they could profit by trading CDS without holding bonds. Therefore, CDS trading volume increased rapidly (Portes, 2010) since 2000 and reached a remarkable market size of $62 trillion in 2007 (Chang et al., 2019). The current market size was $8.8 trillion by the end of June 2021 (ISDA, 2021).

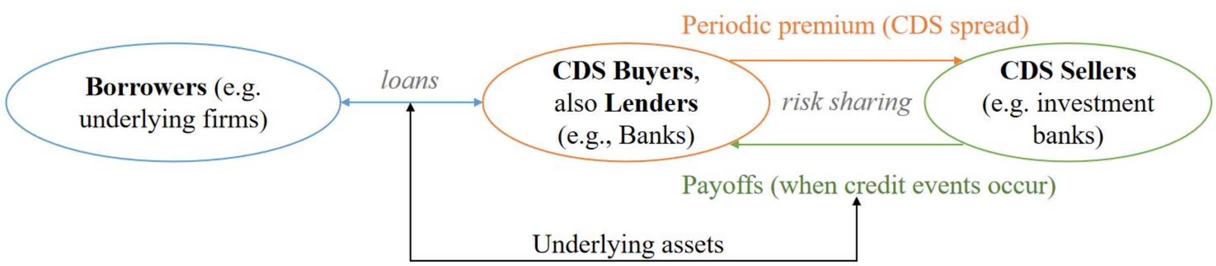

Figure 1. How a CDS Works

CDS has a profound and far-reaching impact on enterprises and markets. It serves as one key indicator of the financial status of firms. Moreover, the CDS spread data of the reference company can remind the regulators to pay attention to potential problems of individual banks, security companies, or insurance companies (Terzi and Uluçay, 2011). Most existing studies thus focus on its financial implications. One mainstream literature focuses on CDS' impact on lenders' incentives to engage in costly monitoring (e.g., Bolton and Oehmke, 2011). Another stream is the increased credit supply enabled by CDS inception (e.g., Saretto and Tookes, 2013; Shan et al., 2015; Ivanov et al., 2016). Other research investigates the influence of CDS on bond market (Ashcraft and Santos, 2009; Shim and Zhu, 2014). In particular, after the 2008 financial crisis, there has been academic research on the impact of CDS on financial market stability (Terzi and Uluçay, 2011). While extensive research has been conducted on the financial implications of CDS, there is still a limited understanding of the operational implications of CDS—that is, if and how CDS may affect other aspects of a firm's operations, such as IT investment.

Information technology (IT) is one strategic source of sustainable competitive advantage for firms. Much empirical evidence shows that IT can significantly improve a company's performance and market position (Dehning and Stratopoulos, 2003). IT is also vital in firms' daily operational processes to achieve efficiency (McAfee and Brynjolfsson, 2008). Therefore, IT investment is a key decision of business organizations. IT investment can be broadly defined as the investments and expenditures directly associated with a firm's IT function (Kobelsky et al., 2008). Paying IT suppliers and service providers, replacing outdated hardware or software, training IT personnel and system users, and developing or implementing new information systems and/or application software portfolios are just a few examples. Existing literature provides several insights regarding factors that influence IT investment, such as firms' scale and scope, governance pattern, managerial processes, board interlocks, and industry characteristics (Dewan et al., 1998; Kobelsky et al., 2008; Cheng et al., 2021). However, understanding of the potential impact of firms' financial status on IT investment is limited.

In view of the significant impacts of CDS on corporate finance and the role of IT investment in firms' strategic/operational decision-making, we thus aim to examine the impact of CDS trading on firms' IT investment and further investigate the mechanism underlying this impact. Considering the costly and risky nature of IT investment, firms may need financial support, and CDS is a financial instrument that serves debt financing. Moreover, IT investments are of operational and strategic significance. From an operational perspective, fixed and continuous investment makes IT investment a cost center, such as PCs, office software, system maintains and updates, and so on. From the strategic perspective, strategic IT investments such as enterprise systems face risks of failure (Wimelius et al., 2020). CDS may impact IT investment as a financial innovation that mitigates default risks for lenders. Given the abovementioned perspectives, CDS and IT investment are inextricably linked. Our study aims to provide empirical evidence on this key relationship.

We collect and match data about CDS trading, IT investment, and financials of firms from different sources—GFI Group, Compustat database, and Computer Intelligence, respectively. We find from our empirical study that CDS trading significantly decreased reference firms' IT investment. Specifically, most of the reduction of IT investment was in software than hardware expenditure. Furthermore, we perform the analysis of the credit-risk mechanism underlying the negative relationship between CDS trading and IT investment, particularly in software. Finally, we conduct several cross-sectional tests to demonstrate that the influence of CDS on IT investment is particularly pronounced for firms that heavily rely on debt financing, belong to high-tech industries, and have stable earnings.

The remainder of the paper is organized as follows. In Section 2 we review the related literature. In Section 3 we develop our hypothesis. Section 4 describes our data collection, the variables, and the method in our empirical analysis. Section 5 provides the baseline empirical results with a series of endogeneity tests. Section 6 provides the mechanism test for the mediating effect of credit risk. In Section 7 we conduct subgroup tests. We conclude this paper in Section 8.

1.2 Literature review

Our paper builds on two strands of literature: recent studies that focus on the consequences of CDS trading and research on the determinants of IT Investment.

1.2.1 Consequences of CDS trading

One stream of CDS's financial implications emphasizes on the transferring of credit risk on CDS inception. With the advent of CDS trading, the credit risk of the underlying company's creditors is transferred to CDS sellers. Once credit risk is hedged, insured lenders are less inclined than before to carry out expensive monitoring (Martin and Roychowdhury, 2015). Moreover, lenders have less incentives to intervene in underlying firms' governance and operations (Parlour and Winton, 2013). Ashcraft and Santos (2009) illustrate one example that can benefit the lending parties is that banks have increasingly adopt CDS to transfer credit risk exposure to the third party CDS seller. Parlour and Winton (2013) compare credit risk transferring strategies between loan sales and CDS trading. Martin and Roychowdhury (2015) reveal that, once monitoring is reduced, underlying firms can report financial performance less conservatively and embark on risky projects.

Another area of research in the literature examines the increase of lenders' credit supply to businesses with the help of CDS trading (Bolton and Oehmke, 2011). According to Saretto and Tookes (2013), the beginning of CDS trading has a direct impact on the increase in lenders' willingness to lend. Borrowing firms in turn have higher debt capability and have higher leverage. More risky projects can be financed and invested (Bolton and Oehmke, 2011). Subrahmanyam et al. (2014) prove that underlying firms hold more cash after CDS trading introduced on their debt. In another study, Subrahmanyam et al. (2017) comment that borrowing firms that involve in CDS trading face higher bankruptcy risk. Fuller et al. (2018) point out that CDS trading can increase not only borrowing firms' credit supply but also affect other economically connected firms because firms with CDS trading tend to increase equity issuance. In another study, Chang et al. (2019) point out that CDS trading effectively boosts firms' risky innovation, especially for projects that rely on debt financing.

CDS trading also has an impact on bond market. Specifically, Ashcraft and Santos (2009) propose two channels though which CDS influences the bond market. One mechanism is that CDS can hedge lender's credit risks, thus reducing bonds' risk premium. Another mechanism is that CDS trading further reduces market information asymmetry and hence lower bond cost. Shim and Zhu (2014) summarize that, overall, CDS trading helps lower the cost of bond issuance and increases bond market liquidity. Oehmke and Zawadowski (2015) find out that CDS trading encroaches bond demand but increases bond market allocation efficiency by providing long-term bond holders with leverage. Borrowing costs can thus be raised once naked CDSs are banned. Czech (2021) in recent research reveals that CDS trading has a spillover effect that can effectively increase bond market trading volume to 70%.

Little studies explored the effect of CDS trading on underlying firms' operations. Chang et al. in 2019 examine the effect of CDS trading on corporate innovation. Qiu et al. in 2022 study the effect of CDS trading on firms' operation efficiency. Based on their research, we will empirically investigate the effect of CDS trading on firms' operations from IT investment.

1.2.2 Determinants of Firm IT investment

Another stream of literature that relates to our study is IT investment. According to McAfee and Brynjolfsson (2008), IT investment is essential to firms' competitiveness. To measure IT investment, Khallaf (2012) separate the understanding of IT investment with respect to its accounting treatment. In other words, IT investment can be classified into software and hardware streams. Cheng et al (2021) propose to measure firm IT investment from a strategic significance perspective. They suggest two categories. IT investment in applications for enterprise CRM purpose represents one category. Another category is labor expense resulting from IT.

Our review of IT investment studies focuses on the determinants of firms' IT investment. In other words, we would like to explore what aspects that can either increase or deter firms' IT adoption. Dewan et al. (1998) investigate the linkage between IT investments and firms' scale and scope. More diversified firms are found to have higher IT investment for asset coordination purpose. Dasgupta et al. (1999) propose several aspects that significantly affect firms' IT adoption. Corporation factors such as firms' culture and scale, environmental factors such as market competition, external factors such as government policies, exchange rates and IT hardware prices can all exert significant influence on firms' IT adoption. The role of management information systems personnel is found to have a negative impact on firms' IT adoption. Kobelsky et al. (2008) explore the determinants of firms' IT budget and suggest a causal effect between IT budget with shareholder's returns and firms' performances. Alam and Noor (2009) summarize five factors, such as perceived benefits, perceived costs, IT knowledge, external pressure, and government support as the determinants of IT investment with empirical evidence from Malaysian service sectors. For banking system, Ou et al. (2009) show that operating size, deposit level and operating cost all have significant influence on banks' IT investment, proxied by ATM investment. Ravichandran and Liu (2011) analyze environmental components, from both industry and information perspectives, that affect IT investment strategies. Ghobakhloo et al. (2012) focus on small and medium sized firms (SME)' IT investment and find out driving forces from both external and internal perspectives. Specifically for internal factors, they mention the impact of IT users, firm owners' characters, organizational behaviors, and firm's resources. Hanclova et al. (2015) conduct similar research with respect to SMEs and propose more determinants such as data resources, IT systems' function modules, IT properties and IT operation methods.

1.3 Hypothesis Development

We develop our main hypothesis according to three channels through which CDS trading may influence IT investment—i.e., the financing channel, the risk-taking channel, and the credit risk channel.

The primary effect via the financing channel is that lenders are more inclined to lend capital to borrowers under CDS trading. This is due to two key factors. First, by acquiring CDS, lenders shift credit risk to CDS sellers (Martin and Roycowdhury, 2015). Therefore, lenders are more ready to lend since the credit risk they face has been substantially decreased. Second, the insurance nature of CDS considerably improves the lenders' bargaining position in debt restructuring (Bolton and Oehmke, 2011). Third, the price fluctuation of credit default swaps reflects the business conditions of companies and lowers the information asymmetry between lenders and borrowing companies. Therefore, lenders lower their credit risk and improve their awareness of the operational circumstances of underlying enterprises via CDS transactions, and they are in a better position to lend more capital to firms. IT budget, especially at the operational level, demands continuous and hefty investments (Kobelsky et al., 2008). Once obtain sufficient capital with the help of CDS trading, firms can thus spend more on IT. Therefore, CDS trading could increase the underlying firm's IT investment.

CDS trading not only has the potential to increase the available capital for firms, but also may lead to risk-taking behaviors of firms, such as strategic IT investment. As previously stated, strategic IT expenditures are associated with risk. A borrowing firm may spend substantial money on strategic IT investments, yet these investments may not boost firm performance as anticipated (Chang et al., 2019). Once the company's strategic IT investments fail to generate expected returns, it will harm the company's operations and anticipated earnings. In view of the repayment of loans and interest rates, lenders have limited tolerance for the risk-taking behaviors of the underlying firms and have strong incentives to monitor the company's operations. However, CDS trading may mitigate lenders' concern over risk and reduce their monitoring incentives by transferring default risk to CDS buyers. For instance, the price fluctuations in CDS transactions may convey information about the underlying company's operations. After gaining more knowledge about the borrower's business, the lender may no longer constantly scrutinize its every action. Hence, CDS transactions diminish the lender's monitoring incentives (Saretto and Tookes, 2013). With lenders' loosened monitoring, underlying firms may spend more on high-risk projects (Subrahmanyam et al., 2014) and engage in high-risk activities, such as strategic IT investment (Chang et al., 2019). Thus, CDS trading can increase firms' IT investment via the risk-taking channel.

On the other hand, CDS trading may lead to a decrease in IT investment. Existing studies show that the introduction of CDS will reduce the credit rating of underlying firms and even increase their default risk (Subrahmanyam et al., 2014). As discussed above, borrowers under CDS trading can get more financing. This will further increase their leverage ratio and interest burden, thus resulting in even greater financial constraints for the borrowing firms. In addition, once the CDS transaction starts, the underlying companies that have been in financial distress are more likely to file for bankruptcy under the pressure of lenders. This is because if the CDS compensation value induced by the bankruptcy of a borrowing firm is greater than that acquired in the debt restructuring, the lender has the incentive to force the bankruptcy of the reference firm. With such an increase in credit risk, underlying firms may reduce their IT investment to decrease their risk exposure. Therefore, from a credit risk perspective, CDS trading could decrease the underlying firm's IT investment.

We plot the three potential mechanisms in Figure 2. Given these competing effects, the net magnitude of the impact of CDS trading on IT investment is an empirical question. Thus, we restrain from making directional predictions and instead state the hypothesis in the null form as follows[1]:

Hypothesis (null): CDS trading has no effect on underlying firms' IT investment.

[1] Another form of our null hypothesis is: The CDS trading will increase IT investment if the effects through financial channel and risk-taking channel dominate the effects through credit risk channel; If vise versa, the CDS trading will lower IT investment.

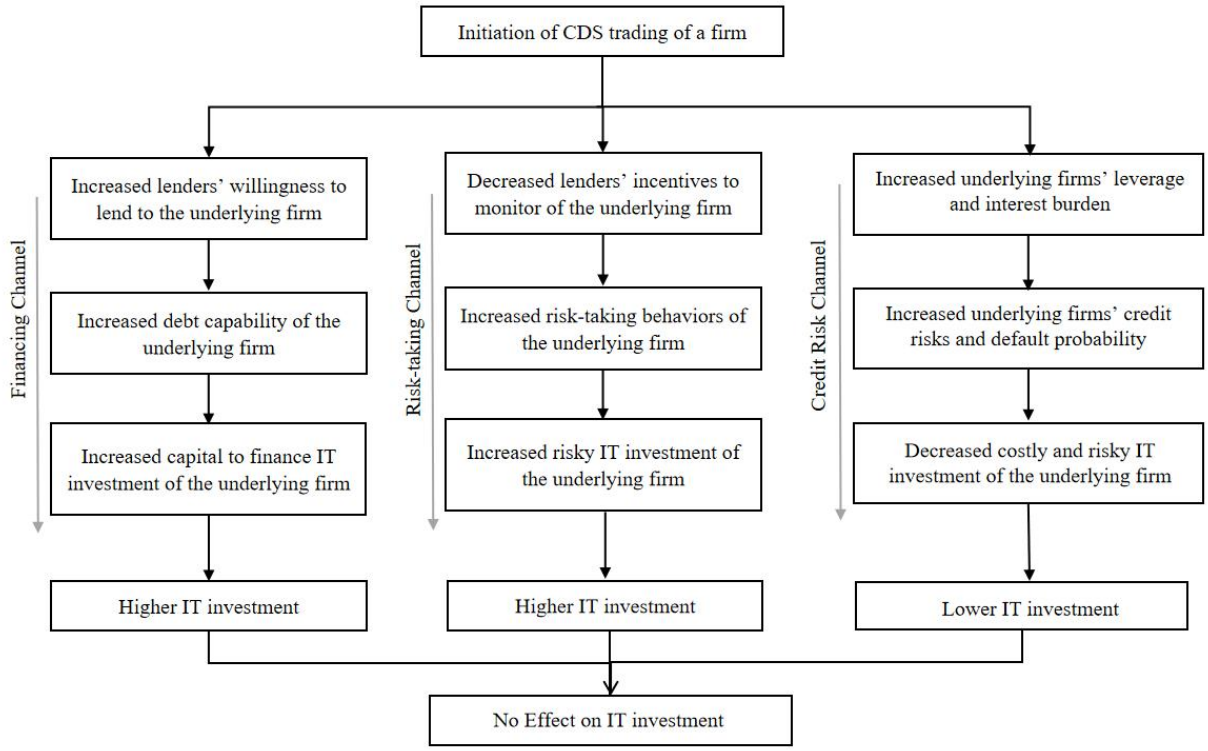

Figure 2. Theoretical Framework

1.4 Methodology

1.4.1 Data and Sample

We collected data from several sources. First, we acquired CDS trade data from "GFI Group," a reputable CDS market interdealer broker. The information includes single-name CDS trading statistics for North America from 1998 to 2007[2]. Second, we obtained firm-level financial data from the Compustat database (Subrahmanyam et al., 2014). Finally, we gathered data about firms' IT investment from the Harte Hanks Computer Intelligence Technology Database (CITDB), which has been widely used as a reliable data source that contains detailed information about the IT infrastructure of more than 500,000 enterprises in the United States (Cheng et al., 2021). Our IT investment data covers the period of 1999 to 2008. As it takes time for the effects of CDS trading to manifest, there is a one-year lag between the commencement of CDS trading and enterprises' IT investments (Chang et al., 2019). We then merged the afore-mentioned data as the final sample. We drop observations from financial industries. We also drop

[2] After 2008, there was a structural change of CDS trading due to the financial crisis. We thus include CDS trading data before 2008.

observations that have missing control variables. The whole sample includes 16,265 firm-year observations, representing 2,391 unique firms, 428 of which initiated CDS trading during the period of 1997 to 2007.

In Table 1, we report the sample distribution of CDS firms. In Panel A of Table 1, we first show the distribution of CDS firms by year of initiation. The start date is the first day of CDS trading. The introduction year is the first CDS active year. The number of newly initiated CDS firms ranges from 3 firms in the year of 2007 to 97 firms in the year of 2002. In Panel B of Table 1, we report final sample distribution on a yearly basis. The table reports the total number of total firm-year observations and CDS active firm-year observations for each year. The number of firms ranges from 1,398 firms in the year of 2007 to 1,671 firms in the year of 2003. The percentage of CDS-active firms in total firm-year observations ranges from 2.15% in the year of 1998 to 27.4% in the year of 2007.

Table 1. Sample Distribution

Panel A. CDS Firm Distribution by Year of CDS Initiation

Initiation year	N	% in total CDS firms	Cumulative N	Cumulative % in total CDS firms
1997	12	2.80%	12	2.80%
1998	30	7.01%	42	9.81%
1999	27	6.31%	69	16.12%
2000	65	15.19%	134	31.31%
2001	90	21.03%	224	52.34%
2002	97	22.66%	321	75.00%
2003	43	10.05%	364	85.05%
2004	30	7.01%	394	92.06%
2005	24	5.61%	418	97.66%
2006	7	1.64%	425	99.30%
2007	3	0.70%	428	100.00%
Total	428	100.00%	428	100.00%

Panel B. Sample Distribution by Year

Fyear	N	CDS active firm-year observations	% of CDS active firms in total firm-year observations
1998	1724	37	2.15%
1999	1739	64	3.68%
2000	1652	120	7.26%
2001	1663	208	12.51%
2002	1663	302	18.16%

2003	1671	343	20.53%
2004	1653	370	22.38%
2005	1587	390	24.57%
2006	1515	397	26.20%
2007	1398	383	27.40%
Total	16265	2614	16.07%

1.4.2 Variables

Dependent Variables. The dependent variables are firms' IT investments. We measure firms' IT investment using three variables. The first measurement is IT hardware investment, represented as $HARDWARE_{i,t}$. It is proxied by the market value of IT hardware stock. We determine it by multiplying the number of personal computers (PCs) and servers at each company by the average prices of a PC and a server respectively. The average prices are the average level of that year, which are from the Economist Intelligence Unit Telecommunications database (Nagle, 2018). The second measurement is IT software investment, represented by $SOFTWARE_{i,t}$. A widely adopted proxy for investment in IT software and services is IT labor expense (Hitt and Brynjolfsson 1996). We calculate it by the number of IT staff members of each firm by mean annual wage for all computer and mathematical science workers (Nagle, 2018). $TOTAL_{i,t}$ is the summation of software and hardware investment.

Key Independent Variable. The key independent variable is CDS trading). $CDS_{i,t}$ is a dummy variable that represents whether CDS is available to firm *i* at time t. It equalizes 1 after the firm initiates CDS trading, otherwise 0.

Control Variables. Following prior CDS research, we adopt firms' financial indicators as control variables (Subrahmanyam et al., 2014; Chang et al., 2019). $SIZE_{i,t}$ stands firm size. It is the natural logarithm of a firm's total assets. $ROA_{i,t}$ is return on assets. $LEVERAGE_{i,t}$ is defined as a company's total liability divided by its total assets. $UNCERTAINTY_{i,t}$ is the standard deviation of firms' earnings in past 5 years. $DIVERSIFICATION_{i,t}$ is the natural logarithm of one plus number of business segments. $GROWTH_{i,t}$ measures firm's sales growth. $INDUSTRY\ CONCENTRATION_{i,t}$ calculates the four-firm concentration ratio, which is the percentage of an industry's total sales (at the 3-digit SIC level) accounted for by its four largest firms. $CREDIT\ DUMMY_{i,t}$ is a dummy variable that equalizes 1 if a firm has a

Standard & Poor's debt rating, otherwise 0. $MARKET\text{-}TO\text{-}BOOK_{i,t}$ is a firm's market value divided by its book value. $CASH_{i,t}$ is a firms' cash holdings and is measured by a firm's cash divided by total assets. $INSTITUTIONAL\ OWNERSHIP\ RATIO_{i,t}$ is a firm's total institutional ownership ratio. $INVESTMENT\ GRADE_{i,t}$ is a dummy variable to capture firms' credit risk.

The summary statistics for our final sample are shown in Table 2. At the 1% and 99% levels, all the variables are winsorized. The average number of observations with active CDS firm-years is 16.1%. Regarding the features of the company, the mean (median) value of business size in terms of total assets is 6.418 (6.416) in natural logarithm, which is equivalent to real value of 612.78 million (611.55 million). Additionally, the ROA profitability is 6.9% (8.1%) on average (median). Total liability for the company divided by total assets has a mean (median) value of 0.546 (0.535). Standard deviation of firms' earnings for the past five years has a mean (median) of 0.079 (0.036). Natural logarithmically, the average (median) of one plus firms' number of business segments is 1.174 (1.099), or 2.23 (2.00) in actual value. Sales growth has a mean (median) value of 10.4% (7.6%). The four-firm industry concentration ratio has a mean (median) value of 0.601 (0.582). About 40.6% of our final observations have a Standard & Poor's rating for their debt. Firm's market value divided by its book value is 0.542 (0.479) on average (median). The firm's cash holdings comprise 12.7% of total assets. And the average institutional ownership ratio of our final observation is 49.5%. Investment grade of the firms has an average level of 17.731 and median of 23.

Table 2. Summary Statistics

Variable	N	Mean	S.D.	Median	Q1	Q3	Min	Max
$TOTAL_{i,t}$	12677	3.674	58.495	0.889	0.243	2.421	0.000	3477.92
$HARDWARE_{i,t}$	16265	0.348	3.285	0.133	0.043	0.317	0.000	180.571
$SOFTWARE_{i,t}$	12677	3.298	53.944	0.710	0.099	2.076	0.000	3211.075
$CDS_{i,t}$	16265	0.161	0.367	0.000	0.000	0.000	0.000	1.000
$SIZE_{i,t}$	16265	6.418	2.009	6.416	4.977	7.825	2.045	10.903
$ROA_{i,t}$	16265	0.069	0.121	0.081	0.037	0.130	-0.547	0.326
$LEVERAGE_{i,t}$	16265	0.546	0.256	0.535	0.370	0.685	0.094	1.581
$UNCERTAINTY_{i,t}$	16265	0.079	0.131	0.036	0.018	0.082	0.003	0.898
$DIVERSIFICATION_{i,t}$	16265	1.174	0.500	1.099	0.693	1.609	0.693	2.303
$GROWTH_{i,t}$	16265	0.104	0.249	0.076	-0.013	0.182	-0.537	1.199
$INDUSTRY\ CONCENTRATION_{i,t}$	16265	0.601	0.208	0.582	0.433	0.760	0.210	1.000
$CREDIT\ DUMMY_{i,t}$	16265	0.406	0.491	0.000	0.000	1.000	0.000	1.000
$MARKET\text{-}TO\text{-}BOOK_{i,t}$	16265	0.542	0.893	0.479	0.276	0.768	-5.086	3.696
$CASH_{i,t}$	16265	0.127	0.157	0.060	0.018	0.177	0.000	0.705
$INSTITUTIONAL\ OWNERSHIP\ RATIO_{i,t}$	16265	0.495	0.313	0.542	0.216	0.755	0.000	1.082
$INVESTMENT\ GRADE_{i,t}$	16265	17.731	6.745	23.000	11.000	23.000	1.000	23.000

Note: Software related measures are only from 2000-2004 due to database data collection change

1.5 Empirical Results

1.5.1 Baseline Analysis

In this part, we investigate how financial innovation - specifically, lenders' availability to CDS trades - has affected a focal firm's IT investment. We calculate the regression model shown below:

$$IT\ Investment_{i,\,t+1} = \beta_0 + \beta_1 \times CDS_{i,\,t} + \beta_2 \times Controls + \delta \times Firm_i + \theta \times Year_t + \varepsilon \quad (1)$$

We run linear regression using a DiD method. $CDS_{i,\,t}$ represents $CDS\ firm \times post\ effect$. The conventional DiD equation is simplified to $CDS_{i,\,t}$ with firm and year fixed effects when both firm and time fixed effects are included in the model (Chang et al., 2019).

The dependent variable is $IT\ Investment_{i,\,t+1}$, which is IT investment for firm i in year $t+1$. The dependent variable is lagged by one year because it takes time for lenders and other stakeholders to pay attention to the CDS initiating company and then take measures to influence its IT investment by increasing funding and decreasing monitoring. The key independent variable is $CDS_{i,\,t}$, a dummy variable indicating that if firm i initiates CDS trading in year t. Firm size is included as a control variable (Hendricks et al., 2009). Because firms' strategies are closely related to profitability, we include return on assets and sales growth as control variables. Leverage is also a crucial financial indicator. We include liability divided by total assets. To learn the uncertainty of firm's profitability, we control for firms' earnings in past five years. Diversification is included to measure firm's business segments (Dewan et al., 1998). We use a dummy variable to control for the firm's credit rating, which equalizes to 1 if the firm has a Standard & Poor's debt rating. Market-to-book value is included as a firm's market value divided by its book value. Cash holdings is controlled as a firm's operational resource. To gauge competition in this market, industry concentration ratio is controlled. To control for enterprises' institutional governance level, we also include the institutional ownership ratio. Credit risk is controlled using credit rating. Additionally, we incorporate year and company fixed effects in the regression for the unobservable fixed effect.

In Table 3, we display the baseline regression results. We provide the robust t and bootstrap z statistics, and all the standard errors are clustered at the firm level to address the concern that the model may not satisfy common regression assumptions (such as clustering and heteroscedasticity). In column (1) to (3), we report the regression results regarding CDS's impact on total investment. In column (2) (robust t statistics) and (3) (bootstrap z statistics), we find that the coefficient of CDS trading on firms' total IT investment is significantly negative, suggesting that the initiation of CDS trading reduces firm's total IT investment. Economically, the CDS trading can reduce firm's total IT investment by 16.5%. Specifically, we analyze the total investments in terms of software and hardware respectively. In column (7) to (9), we report the effect of CDS trading on firms' software investment. The results are also significantly negative, suggesting that CDS trading decreases firms' software investment. Economically, the CDS trading can reduce firm's software IT investment by 19.2%. Column (4) to (6) report the effect of CDS trading on firms' hardware investment. However, the results are not statistically significant.

We may conclude that CDS trading overall has a negative impact on firm's IT investment, and the magnitude is more significant in software investment, revealing that firms' IT investment decreases most in software on inception of CDS trading. The baseline results reject the *Hypothesis (null)*, indicating a negative impact of CDS trading on firms' IT investment.

Table 3. Baseline Regression

	(1) *TOTAL*	(2) *TOTAL*	(3) *TOTAL*	(4) *HARDWARE*	(5) *HARDWARE*	(6) *HARDWARE*	(7) *SOFTWARE*	(8) *SOFTWARE*	(9) *SOFTWARE*
$CDS_{i,t}$	**-1.144*****	**-0.609*****	**-0.609*****	**-0.025****	**0.009**	**0.009**	**-1.119*****	**-0.633*****	**-0.633*****
	(-5.109)	**(-3.976)**	**(-3.578)**	**(-2.111)**	**(1.400)**	**(1.529)**	**(-5.290)**	**(-4.327)**	**(-4.100)**
$SIZE_{i,t}$		-2.053***	-2.053***		-0.139***	-0.139***		-1.827***	-1.827***
		(-3.373)	(-3.354)		(-17.326)	(-18.127)		(-3.215)	(-3.148)
$ROA_{i,t}$		-5.917	-5.917		0.008	0.008		-5.333	-5.333
		(-0.952)	(-0.914)		(0.248)	(0.262)		(-0.915)	(-0.926)
$LEVERAGE_{i,t}$		-2.502	-2.502		-0.029	-0.029		-2.531	-2.531
		(-0.858)	(-0.833)		(-1.440)	(-1.481)		(-0.925)	(-0.981)
$UNCERTAINTY_{i,t}$		16.637	16.637		0.096**	0.096**		15.510	15.510
		(1.313)	(1.303)		(2.257)	(2.300)		(1.305)	(1.363)
$DIVERSIFICATION_{i,t}$		0.772**	0.772**		0.009	0.009		0.740**	0.740**
		(2.170)	(2.533)		(1.228)	(1.432)		(2.194)	(2.142)
$GROWTH_{i,t}$		-1.344	-1.344		-0.010	-0.010		-1.297	-1.297
		(-0.880)	(-0.797)		(-1.498)	(-1.344)		(-0.906)	(-0.934)
INDUSTRY $CONCENTRATION_{i,t}$		5.444	5.444		0.009	0.009		5.064	5.064
		(0.953)	(0.948)		(0.248)	(0.240)		(0.944)	(0.951)
CREDIT $DUMMY_{i,t}$		2.707***	2.707***		0.027	0.027		2.548***	2.548***
		(3.705)	(3.317)		(1.200)	(0.798)		(3.709)	(3.147)
MARKET-TO-$BOOK_{i,t}$		-2.211	-2.211		-0.004	-0.004		-2.064	-2.064
		(-0.955)	(-0.892)		(-1.124)	(-1.119)		(-0.950)	(-0.960)
$CASH_{i,t}$		0.151	0.151		-0.080***	-0.080**		0.378	0.378
		(0.105)	(0.092)		(-2.826)	(-2.556)		(0.278)	(0.244)
INSTITUTIONAL OWNERSHIP $RATIO_{i,t}$		-0.214	-0.214		0.005	0.005		-0.334	-0.334
		(-0.276)	(-0.264)		(0.257)	(0.292)		(-0.453)	(-0.505)
INVESTMENT $GRADE_{i,t}$		Yes	Yes		Yes	Yes		Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.442***	11.546**	11.546***	0.351***	1.104***	1.104***	1.044***	10.034**	10.034**

	(12.941)	(2.241)	(2.914)	(23.271)	(19.890)	(17.089)	(9.632)	(2.077)	(2.563)
N	12677	12677	12677	16265	16265	16265	12677	12677	12677
R2	0.002	0.012	0.012	0.002	0.123	0.123	0.002	0.012	0.012

t statistics in parentheses
** p < 0.1, ** p < 0.05, *** p < 0.01*

1.5.2 PSM

CDS trading might be determined endogenously. That is, companies with higher credit risks are more likely to have CDS trading based on their credit event. To overcome this issue, we use two identification strategies: (I) a regression using the matched sample; and (II) a Heckman-two stage model.

We first utilize PSM to establish a control group for the treatment group—i.e., firms with CDS trading—following existing studies (e.g., Goh et al. 2013, Li 2016, Kumar et al. 2018, Bapna et al. 2019, and Khurana et al. 2019). The PSM matching procedure goes like the following. Given that our focus is on estimating the likelihood of the initiation of CDS trading, we follow Chang et al. (2019) and Subrahmanyam et al. (2014) and only keep the observations from 1998 to 2007 for non-CDS businesses and the observations from one year prior to the CDS initiation for CDS firms. We then randomly order all the observations and run a logit model to estimate the propensity scores, while adjusting for any observable traits of the firms that could have an impact on CDS trading in the year prior to CDS initiation. We acquire the PSM-matched sample by pairing each CDS firm with one non-CDS firm that has the closest propensity score. The following is the logit regression model:

$$Logit(CDS_{i,t}) = \beta_0 + \beta_1 \times Controls_{i,t-1} + \delta \times Firm_i + \theta \times Year_t + \varepsilon \qquad (2)$$

Next, we obtain all the observations from 1998 to 2007 for the PSM-matched firms and use the new sample created to conduct the PSM-DiD test by re-estimating our regression equation (1). The comparison of the summary statistics of the treatment group and control group before and after PSM are shown in the Online Appendix (Table 3). Table 4 reports our findings. Overall, CDS trading decreases IT investment, which is consistent with the results from our baseline analysis. Specifically, CDS trading decreased both firms' hardware and software investments.

Table 4. Test on PSM-Matched Sample

	(1) *TOTAL*	(2) *TOTAL*	(3) *TOTAL*	(4) *HARDWARE*	(5) *HARDWARE*	(6) *HARDWARE*	(7) *SOFTWARE*	(8) *SOFTWARE*	(9) *SOFTWARE*
$\boldsymbol{CDS_{i,t}}$	**-0.532*** **	**-0.302** **	**-0.302*** **	**-0.037*** **	**-0.021** **	**-0.021** **	**-0.492*** **	**-0.282** **	**-0.282*** **
	(-3.489)	**(-2.526)**	**(-2.622)**	**(-2.806)**	**(-2.178)**	**(-2.552)**	**(-3.534)**	**(-2.544)**	**(-3.537)**
$SIZE_{i,t}$		-2.105***	-2.105***		-0.182***	-0.182***		-1.893***	-1.893***
		(-4.879)	(-6.258)		(-4.131)	(-4.550)		(-4.953)	(-8.615)
$ROA_{i,t}$		-2.748*	-2.748		-0.147	-0.147		-2.528*	-2.528*
		(-1.832)	(-1.431)		(-1.115)	(-1.251)		(-1.857)	(-1.780)
$LEVERAGE_{i,t}$		2.796**	2.796***		0.149*	0.149**		2.633***	2.633***
		(2.532)	(3.286)		(1.877)	(2.174)		(2.588)	(3.569)
$UNCERTAINTY_{i,t}$		10.600***	10.600***		0.756***	0.756***		9.729***	9.729***
		(3.126)	(2.985)		(2.823)	(2.863)		(3.133)	(4.489)
$DIVERSIFICATION_{i,t}$		0.218	0.218		0.026	0.026**		0.187	0.187
		(0.944)	(0.902)		(1.400)	(2.309)		(0.876)	(1.410)
$GROWTH_{i,t}$		0.386	0.386*		0.030	0.030		0.347	0.347**
		(1.618)	(1.706)		(1.357)	(1.458)		(1.625)	(2.104)
INDUSTRY $CONCENTRATION_{i,t}$		1.148	1.148**		0.125*	0.125		1.020	1.020
		(1.478)	(2.186)		(1.891)	(1.542)		(1.407)	(1.522)
CREDIT $DUMMY_{i,t}$		1.390**	1.390***		-0.028	-0.028		1.420***	1.420**
		(2.517)	(2.622)		(-1.074)	(-0.993)		(2.697)	(2.421)
MARKET-TO- $BOOK_{i,t}$		0.233	0.233		0.047**	0.047*		0.168	0.168
		(1.120)	(1.277)		(2.295)	(1.795)		(0.891)	(0.633)
$CASH_{i,t}$		-0.284	-0.284		-0.032	-0.032		-0.299	-0.299
		(-0.416)	(-0.501)		(-0.546)	(-0.906)		(-0.467)	(-0.431)
INSTITUTIONAL OWNERSHIP $RATIO_{i,t}$		1.168***	1.168***		0.070**	0.070***		1.094***	1.094**

		(2.998)	(3.906)		(2.432)	(3.290)		(3.043)	(2.452)
INVESTMENT GRADE$_{i,t}$		Yes	Yes		Yes	Yes		Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Constant	-0.071	13.850***	13.850***	0.134***	1.432***	1.432***	-0.209*	12.176***	12.176***
	(-0.644)	(4.913)	(5.875)	(19.237)	(5.097)	(5.335)	(-1.953)	(4.863)	(7.566)
N	4837	4837	4837	6104	6104	6104	4837	4837	4837
R2	0.046	0.185	0.185	0.008	0.311	0.311	0.049	0.172	0.172

t statistics in parentheses
** p < 0.1, ** p < 0.05, *** p < 0.01*

One endogeneity issue concerns reverse causality. For instance, firms would first decrease their investment in IT. The decrease in IT investment may be a signal of change in IT-related strategy or unstable operations, which would increase the creditors' concerns about firms' operation risks, and eventually increase the likelihood of CDS trading initiation of underlying firms. In our baseline results, the dependent variable is IT investment in the year after the CDS trading, meaning that the decrease in IT investment occurs after the CDS trading. Thus, reverse causality concerns could be relatively mitigated. Beyond that, we conducted a dynamic DiD test to examine IT investment change trends in years surrounding CDS initiation to further address the issue of reverse causality.

Table 5 summarizes the findings. $YEAR^{-j}$ ($YEAR^{j}$) is the pre-CDS (post-CDS) year indicator that equals 1 in j^{th} year before (after) the first CDS trading year for CDS active firm *i*; otherwise, 0. From the results, we can see that coefficients of $YEAR^{-1}$, $YEAR^{-2}$, $YEAR^{-3}$, $YEAR^{-3^{+}}$ year indicators are insignificant, indicating that prior to the CDS trading initiation, the treatment firms did not experience significant decreases in IT investment, compared with control firms, which further ameliorates the reverse causality concern and also relieve concerns that the negative correlation between CDS trading and IT investment is due to chance or other latent variables in time series. Furthermore, the insignificant coefficients of pre-year indicators also suggests that the parallel trends assumption is not violated.

In addition, the coefficients of post-year indicators show that it takes four years for this impact to become strong and robust (the coefficients of post-third year indicators are marginally significant), and it is a long-lasting effect, since the negative correlation between CDS trading and IT investment remains after four years.

Table 5. Relative Time Model Based on PSM-Matched Sample

	(1) *TOTAL*	(2) *HARDWARE*	(3) *SOFTWARE*
$YEAR^{-3^{+}}$	0.410*	0.011	0.401*
	(1.709)	(0.781)	(1.734)
$YEAR^{-3}$	0.269	0.006	0.262
	(1.575)	(0.617)	(1.608)
$YEAR^{-2}$	0.151	0.004	0.144

	(1.173)	(0.546)	(1.182)
$YEAR^{-1}$	0.014	0.005	0.016
	(0.152)	(1.097)	(0.187)
$YEAR^{1}$	-0.059	-0.011***	-0.051
	(-0.617)	(-2.696)	(-0.552)
$YEAR^{2}$	-0.193	-0.022***	-0.167
	(-1.522)	(-2.679)	(-1.389)
$\boldsymbol{YEAR^{3}}$	-0.286*	-0.029**	-0.253*
	(-1.948)	(-2.368)	(-1.838)
$\boldsymbol{YEAR^{4}}$	-0.445**	-0.037**	-0.406**
	(-2.443)	(-2.338)	(-2.417)
$\boldsymbol{YEAR^{4+}}$	-0.540**	-0.045**	-0.488**
	(-2.466)	(-2.213)	(-2.433)
Controls	YES	YES	YES
Firm Fixed Effect	YES	YES	YES
Year Fixed Effect	YES	YES	YES
N	4837	6104	4837
R2	0.187	0.314	0.174

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

1.5.3 Heckman Two Stage Model

The non-random selection of firms into the CDS trading market raises an endogeneity concern about sample selection bias. We utilize the Heckman two-stage model to address concerns over sample selection bias. First, we use a selection equation to simulate the probability of CDS trading for a company. Then, by controlling the CDS trading probability, we estimate model (1). The equation for selection is as follows:

$$Probit(CDS_{i,t}) = \beta_0 + \beta_1 \times Lender\ Tier\ 1\ Capital_{i,t} + \beta_2 \times Controls_{i,t-1} + \delta \times Firm_i + \theta \times Year_t \quad (3)$$

Where *Lender Tier 1 Capital* is the average level of Tier One capital of the banks that have served as lenders or bond underwriters for *firm i* within the past three years. We identify the firms' lenders and bond underwriters using DealScan data and FISD data. Then, we retrieve information regarding the Tier One Capital of these lenders and bond underwriters from the Bank Regulatory Database and the Compustat Bank file. Because typically lenders (e.g., banks) purchase credit default swaps (CDS) from CDS sellers (e.g., insurance firms, hedge funds) to hedge against the credit risk of the underlying assets, Tier One capital could explain banks' needs of hedging. Tier One capital is an essential indicator of a bank's financial stability. A bank in a strong financial position (with a high level of Tier One capital) would need less credit-risk hedging. Thus, a company with a greater Lender Tier One Capital will have a less likelihood of CDS trading on its debt. Tier One capital is a measure that reflects the financial stability of lenders or bond underwriters rather than the that of the borrowing firms, and it should not immediately impact the firms' IT investment or other channels. Lender Tier One Capital is therefore likely to satisfy the exclusion condition, and we utilize it as the exogenous variable in the selection model (Subrahmanyam et al., 2014). When estimating the selection model, we use data from 1998 to the first year of CDS trading for CDS firms and all observations in our sample for non-CDS firms. Industry (2-digit SIC codes) and year-fixed effects are controlled. Results of the selection model are shown in Table 6(a). After obtaining the inverse mills ratio (IMR) based on the selection model, we add the IMR in the baseline regression model (equation [1]) and re-estimate the effect of CDS on the focal firms' IT investment after correcting the sample selection bias.

Table 6(a). Selection Model of Heckman Correction: Determinant of CDS Trading (Probit Regression)

	(1)
	$CDS_{i,t}$
$LENDER\ TIER\ 1\ CAPITAL_{i,t}$	-0.000***
	(-2.908)
$SIZE_{i,t-1}$	0.828***
	(10.266)
$ROA_{i,t-1}$	2.236***
	(2.588)
$LEVERAGE_{i,t-1}$	0.894**
	(2.538)
$UNCERTAINTY_{i,t-1}$	0.024
	(0.041)
$DIVERSIFICATION_{i,t-1}$	0.073
	(0.617)
$GROWTH_{i,t-1}$	0.216
	(0.922)
$INDUSTRY\ CONCENTRATION_{i,t-1}$	0.035
	(0.080)
$PPENT_{i,t-1}$	0.476**
	(2.039)
$WOKRING\ CAPITAL_{i,t-1}$	0.261
	(0.543)
$CREDIT\ DUMMY_{i,t-1}$	-0.172
	(-0.591)
$MARKET\text{-}TO\text{-}BOOK_{i,t-1}$	-0.112
	(-0.997)
$CASH_{i,t-1}$	-0.914
	(-1.218)
$INSTITUTIONAL\ OWNERSHIP\ RATIO_{i,t-1}$	0.317**
	(2.112)
$INVESTMENT\ GRADE_{i,t-1}$	Yes
Year Fixed Effect	Yes
Industry Fixed effect	Yes
Constant	-9.904***
	(-11.918)
N	7287
R2_P	0.477

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

We present the estimation results of the Heckman correction (second stage) in Table 6(b). These results show that the coefficients of CDS are significantly negative for total IT investment and software IT investment. And after addressing the sample selection bias issue, the decreased level of IT investment due to the inception of CDS enlarges, which is 11.68% on average.

Table 6(b). Results of Heckman Correction

	(1) *TOTAL*	(2) *TOTAL*	(3) *SOFTWARE*	(4) *SOFTWARE*	(5) *HARDWARE*	(6) *HARDWARE*
$CDS_{i,t}$	**-1.057^{***}**	**-0.429^{**}**	**-1.009^{***}**	**-0.440^{**}**	**-0.059^{***}**	**0.010**
	(-5.329)	**(-2.218)**	**(-5.366)**	**(-2.386)**	**(-3.318)**	**(0.577)**
IMR	**1.303^{***}**	**0.476^{*}**	**1.243^{***}**	**0.496^{**}**	**0.080^{***}**	**-0.015**
	(4.937)	**(1.857)**	**(4.974)**	**(2.029)**	**(3.282)**	**(-0.658)**
$SIZE_{i,t}$		-1.202^{***}		-1.086^{***}		-0.122^{***}
		(-13.436)		(-12.808)		(-13.285)
$ROA_{i,t}$		-0.353		-0.325		-0.016
		(-0.770)		(-0.743)		(-0.355)
$LEVERAGE_{i,t}$		-0.494^{*}		-0.485^{*}		-0.013
		(-1.834)		(-1.884)		(-0.519)
$UNCERTAINTY_{i,t}$		0.971		0.826		0.104^{*}
		(1.531)		(1.366)		(1.693)
$DIVERSIFICATION_{i,t}$		0.136		0.136		0.001
		(1.541)		(1.625)		(0.114)
$GROWTH_{i,t}$		-0.085		-0.071		-0.012
		(-0.994)		(-0.866)		(-1.574)
INDUSTRY $CONCENTRATION_{i,t}$		0.572		0.579		-0.007
		(1.424)		(1.529)		(-0.187)
CREDIT $DUMMY_{i,t}$		0.319		0.306		0.025
		(1.199)		(1.251)		(1.089)
MARKET-TO-$BOOK_{i,t}$		-0.160^{***}		-0.153^{***}		-0.010^{**}
		(-3.699)		(-3.693)		(-2.439)
$CASH_{i,t}$		-0.301		-0.171		-0.057
		(-0.726)		(-0.435)		(-1.532)
INSTITUTIONAL OWNERSHIP $RATIO_{i,t}$		0.221		0.197		0.001
		(1.146)		(1.093)		(0.033)
INVESTMENT $GRADE_{i,t}$		Yes		Yes		Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Constant	1.459^{***}	9.236^{***}	1.248^{***}	8.231^{***}	0.203^{***}	1.039^{***}
	(28.504)	(13.808)	(25.713)	(12.952)	(46.589)	(15.221)
N	7352	7352	7352	7352	9438	9438
R2_P						

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

1.6 Channel Tests: Mediation Test

To further investigate how CDS trading decreases' firm's IT investment, our hypotheses suggest that credit risk is one potential mediating element by which firms' IT investment is decreased in the presence of CDS. Using the OLS test, we investigate further the mediating effects of credit risk on firms' IT investment. The following are the regression models for the mediation tests:

$$\begin{cases} Credit\ Risk_{i,\,t} = \beta_0 + \beta_1 CDS_{i,t} + \beta_2 Controls_{i,t}\ + \delta \times Firm_i\ + \theta \times Year_{\,t} + \varepsilon_{it}\ (4) \\ IT\ Investment_{i,\,t+1} = \beta_0 + \beta_1 CDS_{i,t} + \beta_2 Credit\ Risk_{i,t} + \beta_3 Controls_{i,t}\ + \delta \times Firm_i\ + \theta \times Year_{\,t} + \varepsilon_{it}\ (5) \end{cases}$$

We postulate that CDS trading decrease firms' IT investment through financing channel. For model (4), we expect a significantly positive β_1, to describe the increase of CDS trading on credit risk. For model (5), we expect a significant negative β_2, to describe the decrease of credit risk on IT investment. To measure credit risk, we adopt *WW Index* and *Investment Dummy*. The control variables are identical to those in the baseline regression (model 1), and the company and year effects are controlled.

Following Whited and Wu (2006), we use *WW Index* as the Credit Risk measure and report our results in Panel A of Table 7. A firm is regarded more financially constrained if its *WW index* value is higher. The empirical findings show that the introduction of CDS trading could significantly increase the WW index value, which in turn would negatively affect a firm's IT investment. The t statistics tests show that the mediation effect of trade credit is significant.

To validate our finding, we test the credit risk channel again with *Investment Dummy* (*1 Year Forward*). When a company's credit rating is higher than BB+, its *Investment Dummy* is equal to 1, otherwise it is 0. In other words, a firm is regarded to have lower credit risks if its *Investment Dummy* is 1. The results are displayed in Panel B of Table 7. From our tests, the empirical findings show that the introduction of CDS trading has a negative impact on firm's credit dummy, which in turn would negatively affect a firm's IT investment. The t statistics show that the mediation effect of trade credit is significant.

Table 7. Mediation Test

Panel A. WW Index

	(1) *WW INDEX*	(2) *TOTAL*	(3) *SOFTWARE*	(4) *HARDWARE*
$\boldsymbol{CDS_{i,t}}$	**0.003****	**-0.418*****	**-0.448*****	**0.029****
	(2.151)	**(-5.437)**	**(-6.134)**	**(2.110)**
$\boldsymbol{WW\ INDEX_{i,t}}$		**-2.490****	**-2.111****	**-1.085***
		(-2.214)	**(-1.974)**	**(-1.785)**
$SIZE_{i,t}$	-0.039***	-1.505***	-1.348***	-0.342***
	(-37.737)	(-16.555)	(-15.892)	(-3.584)
$ROA_{i,t}$	0.014***	-0.060	0.053	-0.351

	(3.577)	(-0.170)	(0.156)	(-1.641)
LEVERAGE$_{i,t}$	0.008***	-0.330	-0.249	0.067
	(2.863)	(-1.544)	(-1.194)	(0.648)
UNCERTAINTY$_{i,t}$	-0.000	0.584	0.432	0.557**
	(-0.052)	(1.279)	(0.986)	(2.117)
DIVERSIFICATION$_{i,t}$	0.001	0.175**	0.168**	0.026
	(0.874)	(2.303)	(2.285)	(1.366)
GROWTH$_{i,t}$	-0.028***	-0.019	-0.011	-0.025
	(-19.974)	(-0.221)	(-0.126)	(-0.740)
INDUSTRY CONCENTRATION$_{i,t}$	0.008	0.319	0.269	0.165
	(1.529)	(0.806)	(0.716)	(1.313)
CREDIT DUMMY$_{i,t}$	-0.020***	0.944***	0.947***	0.161**
	(-3.885)	(4.046)	(4.235)	(2.109)
MARKET-TO-BOOK$_{i,t}$	0.001**	-0.061	-0.053	-0.024
	(2.271)	(-1.596)	(-1.427)	(-0.752)
CASH$_{i,t}$	-0.028***	-0.346	-0.174	-0.212***
	(-8.936)	(-1.136)	(-0.601)	(-2.928)
INSTITUTIONAL OWNERSHIP RATIO$_{i,t}$	-0.006**	0.132	0.089	0.114
	(-2.193)	(0.714)	(0.516)	(1.343)
INVESTMENT GRADE$_{i,t}$	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes
_cons	-0.056***	8.442***	7.268***	1.914***
	(-8.378)	(15.996)	(14.677)	(5.516)
N	16246	12661	12661	16246
R2	0.504	0.213	0.219	0.045

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Panel B. INVESTMENT DUMMY

	(1) INVESTMENT DUMMY	(2) *TOTAL*	(3) *SOFTWARE*	(4) *HARDWARE*
CDS$_{i,t}$	**-0.025*****	**-0.632*****	**-0.656*****	**0.025****
	(-3.674)	**(-5.020)**	**(-5.496)**	**(2.004)**
INVESTMENT DUMMY$_{i,t}$		**0.346****	**0.317****	**0.052***
		(2.263)	**(2.215)**	**(1.949)**
SIZE$_{i,t}$	0.045***	-2.407***	-2.152***	-0.296***
	(10.344)	(-12.292)	(-12.087)	(-4.077)
ROA$_{i,t}$	0.082***	0.460	0.541	-0.359
	(4.024)	(0.498)	(0.616)	(-1.644)
LEVERAGE$_{i,t}$	-0.072***	-0.013	-0.089	0.054
	(-5.617)	(-0.020)	(-0.150)	(0.542)
UNCERTAINTY$_{i,t}$	-0.008	3.094**	2.748**	0.556**

	(-0.384)	(2.558)	(2.401)	(2.106)
DIVERSIFICATION$_{i,t}$	0.024***	0.334**	0.320**	0.026
	(4.103)	(1.994)	(2.008)	(1.362)
GROWTH$_{i,t}$	-0.014**	0.133	0.100	0.004
	(-2.236)	(0.628)	(0.504)	(0.142)
INDUSTRY CONCENTRATION$_{i,t}$	0.051*	0.417	0.311	0.167
	(1.714)	(0.550)	(0.434)	(1.343)
MARKET-TO-BOOK$_{i,t}$	-0.004	0.093	0.086	-0.024
	(-1.495)	(0.894)	(0.865)	(-0.750)
CASH$_{i,t}$	-0.091***	-0.536	-0.340	-0.185**
	(-4.780)	(-0.717)	(-0.486)	(-2.444)
INSTITUTIONAL OWNERSHIP RATIO$_{i,t}$	-0.002	-0.420	-0.462	0.128
	(-0.127)	(-1.016)	(-1.190)	(1.436)
INVESTMENT GRADE$_{i,t}$	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes
Constant	-0.051	14.186***	12.466***	1.961***
	(-1.543)	(10.973)	(10.380)	(5.356)
N	16265	12677	12677	16265
R2	0.021	0.135	0.133	0.044

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

1.7 Subgroup Tests

Another related concern is how the effect of CDS trading on firms' IT investment varies according to the characteristics of the firms. To answer this question, we divide the full sample into subgroups based on different company characteristics—namely debt dependence, high technology, and uncertainty—and re-estimate Model (1) to compare the influence of CDS on IT investment across different sub-samples.

Following Rajan and Zingales (1998), we first group firms with respect to their debt dependency. We define debt dependency as the sum of debt issuance divided by the sum of capital expenditures and R&D expenses over the past three years. We divide the firms in the same industry (2-digit SIC code) into two groups based on their debt dependency—i.e., high vs. low debt dependency—by median split. We then re-estimate Equation (1) with each subgroup respectively. The results are displayed in Panel A of Table 8.

We find that, the negative effect of CDS trading on IT investment is only significant for firms that substantially rely on debt financing. Specifically, the effect is significant for total IT investment and software investment, as shown in column (1) and (3). On the contrary, the coefficients are not significant in column (2) and (4). Therefore, the CDS effect is not pronounced for low debt dependency groups. Moreover, there is no significant difference in the coefficient regarding hardware investment between the two groups. We find consistent results with the debt dependence value specified as over the past five years (Table 4 in the Appendix).

Table 8. Subgroup Tests

Panel A. Debt Dependence

	(1)	(2)	(3)	(4)	(5)	(6)
	TOTAL	*TOTAL*	*SOFTWARE*	*SOFTWARE*	*HARDWARE*	*HARDWARE*
	High	Low	High	Low	High	Low
$CDS_{i,t}$	**-0.661*****	**-0.371**	**-0.660*****	**-0.404**	0.006	0.026
	(-3.353)	**(-0.793)**	**(-3.468)**	**(-0.917)**	(0.532)	(1.174)
$SIZE_{i,t}$	-2.560***	-1.796	-2.273***	-1.673	-0.194***	-0.434**
	(-6.647)	(-1.271)	(-6.833)	(-1.255)	(-7.140)	(-2.406)
$ROA_{i,t}$	-1.598	-14.222	-1.087	-13.183	-0.103	-0.475
	(-0.754)	(-0.897)	(-0.573)	(-0.888)	(-0.685)	(-1.400)
$LEVERAGE_{i,t}$	0.128	-7.847	-0.126	-7.508	0.046	0.186
	(0.087)	(-0.837)	(-0.090)	(-0.856)	(0.732)	(0.599)
$UNCERTAINTY_{i,t}$	2.694	35.768	2.040	33.765	0.364***	1.304*
	(1.269)	(1.177)	(1.027)	(1.186)	(2.764)	(1.778)
$DIVERSIFICATION_{i,t}$	0.410	0.977	0.396	0.937	0.005	0.051
	(1.301)	(1.208)	(1.286)	(1.226)	(0.310)	(1.223)
$GROWTH_{i,t}$	0.264	-4.469	0.274	-4.312	-0.031**	0.034
	(1.001)	(-1.017)	(1.055)	(-1.048)	(-1.996)	(0.393)
INDUSTRY $CONCENTRATION_{i,t}$	0.020	12.640	0.031	11.798	0.113	0.075
	(0.014)	(0.960)	(0.021)	(0.954)	(1.027)	(0.245)
CREDIT $DUMMY_{i,t}$	2.264***	0.830	2.068***	0.858	0.103*	0.110
	(3.142)	(0.626)	(3.229)	(0.685)	(1.914)	(1.011)
MARKET-TO- $BOOK_{i,t}$	0.026	-7.717	0.034	-7.217	-0.009	-0.078
	(0.144)	(-0.964)	(0.189)	(-0.961)	(-0.940)	(-0.696)
$CASH_{i,t}$	0.861	-0.684	1.295	-0.512	-0.163*	-0.220*
	(0.518)	(-0.301)	(0.803)	(-0.239)	(-1.674)	(-1.861)
INSTITUTIONAL OWNERSHIP $RATIO_{i,t}$	-0.599	-1.141	-0.745	-1.093	0.047	0.296
	(-1.006)	(-0.590)	(-1.341)	(-0.595)	(1.030)	(1.189)
INVESTMENT $GRADE_{i,t}$	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Constant	15.832***	12.051	13.954***	10.912	1.354***	2.681***
	(5.990)	(1.531)	(5.702)	(1.472)	(7.227)	(3.133)
N	6899	5599	6899	5599	8915	7095
R2	0.104	0.024	0.098	0.024	0.062	0.052

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

In addition, following (Cheng et al., 2021), we classify the firms within the same industry (2-digit SIC code) into two subgroups—namely high-tech vs. non-high-tech subsamples. Similarly, We re-estimate Model (1) with the two subgroups. Panel B of Figure 8 depicts the findings. We find that the negative effect of CDS trading on IT investment is more significant for high-tech firms, indicating that CDS trading introduces a greater risk exposure for high-tech firms probably because these firms are already in high-risk business sectors.

Panel B. High Tech

	(1) *TOTAL*	(2) *TOTAL*	(3) *SOFTWARE*	(4) *SOFTWARE*	(5) *HARDWARE*	(6) *HARDWARE*
	High	Non	High	Non	High	Non
$CDS_{i,t}$	**-1.757***** **(-3.652)**	**-0.425**** **(-2.525)**	**-1.824***** **(-3.826)**	**-0.445***** **(-2.792)**	**0.059**** **(2.096)**	**0.023** **(1.573)**
$SIZE_{i,t}$	-2.816*** (-7.279)	-1.553* (-1.663)	-2.523*** (-7.050)	-1.354 (-1.553)	-0.244*** (-6.283)	-0.314*** (-3.263)
$ROA_{i,t}$	2.640 (1.311)	-10.019 (-1.067)	2.610 (1.349)	-9.127 (-1.038)	0.059 (0.362)	-0.567* (-1.767)
$LEVERAGE_{i,t}$	2.788 (1.547)	-4.740 (-1.183)	2.552 (1.417)	-4.675 (-1.248)	0.142 (1.367)	0.046 (0.321)
$UNCERTAINTY_{i,t}$	-2.634 (-1.216)	23.693 (1.365)	-2.824 (-1.345)	22.231 (1.367)	0.052 (0.259)	0.721** (2.113)
$DIVERSIFICATION_{i,t}$	0.480 (1.373)	0.820** (2.023)	0.436 (1.257)	0.795** (2.066)	0.009 (0.221)	0.026 (1.361)
$GROWTH_{i,t}$	0.019 (0.053)	-1.734 (-0.851)	0.020 (0.057)	-1.673 (-0.876)	-0.016 (-0.466)	0.014 (0.393)
$INDUSTRY CONCENTRATION_{i,t}$	-0.534 (-0.145)	6.962 (1.018)	-0.532 (-0.149)	6.515 (1.015)	-0.250 (-1.005)	0.215 (1.519)
$CREDIT DUMMY_{i,t}$	2.757* (1.764)	1.886** (2.249)	2.589* (1.677)	1.800** (2.238)	0.142* (1.894)	0.133 (1.643)
$MARKET\text{-}TO\text{-}BOOK_{i,t}$	0.133 (0.179)	-2.606 (-0.986)	0.160 (0.225)	-2.439 (-0.983)	0.010 (0.211)	-0.030 (-0.835)
$CASH_{i,t}$	2.056 (1.099)	-0.185 (-0.078)	2.361 (1.300)	-0.013 (-0.006)	-0.083 (-0.714)	-0.224** (-2.125)
INSTITUTIONAL OWNERSHI	-2.845*	0.110	-3.133**	0.021	0.119	0.124

P RATIO$_{i,t}$						
	(-1.744)	(0.122)	(-2.005)	(0.024)	(0.932)	(1.216)
INVESTMENT GRADE$_{i,t}$	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Constant	15.238***	9.437	13.383***	8.032	1.796***	2.053***
	(5.059)	(1.324)	(4.629)	(1.203)	(6.729)	(4.255)
N	2301	10376	2301	10376	2997	13268
R2	0.123	0.014	0.119	0.014	0.084	0.045

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Lastly, we divide the sample by uncertainty, which is calculated as the standard deviation of a firm's ROA over the previous five years (Cheng et al., 2021). We again split the sample into two groups by the year-industry median and re-estimate the baseline regression. Panel C of Table 8 displays the results. The negative impact of CDS trading on IT investment is only significant for firms with stable earnings. Also, the results are significant for total IT investment and software investment. The results imply that CDS trading introduces greater exposure to credit risk for low-uncertainty firms, which in turn reduces their IT investment to a greater extent.

Panel C. UNCERTAINTY

	(1) *TOTAL*	(2) *TOTAL*	(3) *SOFTWARE*	(4) *SOFTWARE*	(5) *HARDWARE*	(6) *HARDWARE*
	High	Low	High	Low	High	Low
CDS$_{i,t}$	**-0.735**	**-0.606*****	**-0.760**	**-0.603*****	0.023	0.000
	(-1.427)	**(-3.874)**	**(-1.571)**	**(-3.973)**	(0.916)	(0.002)
SIZE$_{i,t}$	-2.402***	-1.377***	-2.142***	-1.210***	-0.386***	-0.168***
	(-2.841)	(-7.689)	(-2.713)	(-7.024)	(-2.972)	(-9.023)
ROA$_{i,t}$	-7.088	-4.512***	-6.352	-4.463***	-0.441	-0.014
	(-0.866)	(-2.608)	(-0.828)	(-2.624)	(-1.605)	(-0.138)
LEVERAGE$_{i,t}$	-3.626	-2.331**	-3.656	-2.266**	0.070	-0.059
	(-0.752)	(-2.550)	(-0.808)	(-2.530)	(0.526)	(-1.246)
UNCERTAINTY$_{i,t}$	20.234	17.221*	18.845	16.337*	0.639*	0.709**
	(1.171)	(1.868)	(1.163)	(1.790)	(1.843)	(2.244)
DIVERSIFICATION$_{i,t}$	1.541	0.395*	1.486*	0.377*	0.047	0.014

	(1.618)	(1.897)	(1.651)	(1.851)	(1.066)	(1.171)
$GROWTH_{i,t}$	-1.928	-0.257	-1.885	-0.214	0.024	-0.032**
	(-0.848)	(-0.821)	(-0.885)	(-0.690)	(0.547)	(-2.025)
$INDUSTRY\ CONCENTRATION_{i,t}$	12.679	0.760	11.714	0.787	0.360	-0.055
	(0.851)	(0.834)	(0.837)	(0.888)	(1.249)	(-0.894)
$CREDIT\ DUMMY_{i,t}$	2.772	1.607***	2.604	1.556***	0.176	0.063*
	(1.630)	(3.048)	(1.588)	(2.995)	(1.380)	(1.873)
$MARKET\text{-}TO\text{-}BOOK_{i,t}$	-2.971	-0.189	-2.781	-0.193	-0.029	0.003
	(-0.955)	(-0.702)	(-0.953)	(-0.722)	(-0.672)	(0.325)
$CASH_{i,t}$	0.179	1.307	0.509	1.307	-0.248**	-0.046
	(0.067)	(1.145)	(0.203)	(1.166)	(-2.058)	(-0.857)
$INSTITUTIONAL\ OWNERSHIP\ RATIO_{i,t}$	0.245	-0.160	-0.058	-0.089	0.269*	-0.044
	(0.171)	(-0.357)	(-0.043)	(-0.207)	(1.750)	(-1.390)
$INVESTMENT\ GRADE_{i,t}$	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Constant	7.914	9.773***	6.672	8.365***	2.186***	1.401***
	(0.663)	(7.056)	(0.596)	(6.243)	(3.532)	(10.298)
N	6397	6280	6397	6280	8284	7981
R2	0.014	0.076	0.014	0.076	0.044	0.087

t statistics in parentheses

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

1.8 Conclusion

In this study, we examine the effect of CDS trading on IT investment of underlying firms. We demonstrate that CDS trading can significantly reduce a company's IT investment. Specifically, CDS trading significantly lowers the overall IT investment, and the decreased IT investment is mainly from the software category, not the hardware category. The mechanism of the negative relationship between CDS trading and IT investment is further analyzed. We find that the inception of CDS trading increases the underlying firms' credit risk, lowering IT investment due to the high cost and risk of IT expenditures, especially on software. In addition, we also conduct several subgroup tests and demonstrate that the influence of CDS on IT investment is particularly pronounced for firms with relatively high debt dependency, in the high-tech industry sectors, and having stable earnings. Our research is at the interaction of finance and information systems research. We discuss the implications of our research to both fields in this section.

1.8.1 Theoretical Implications

First, this research addresses a significant gap in the literature on the connection between financial innovations and firms' IT investment. In particular, we provide insights into the linkage from a financial innovation in the market to firms' financial status and ultimately to the high-cost and high-risk IT investment. We take CDS as the focal financial innovation and examine the impact of CDS trading on firm-level IT investment in both software and hardware. Our research offers a comprehensive theoretical explanation of the three potential mechanisms underlying the above relationship: the financing channel, the risk-taking channel, and the credit risk channel. We find empirical evidence of a negative relationship, suggesting the credit risk channel is the dominating mechanism. That is, CDS decreases corporate IT investment by increasing corporate credit risk. We address the endogeneity issues by employing several causal identification methodologies and demonstrating a solid quantitative connection between the introduction of CDS and the IT investment of the underlying firm. Our paper is thus among the first that provides concrete evidence of the general relationship between financial innovations and firms' IT strategy.

Second, our study contributes to the CDS literature in finance by examining an outcome beyond financial consequences. Existing CDS studies have focused on a number of financial outcomes of CDS trading, such as transferring lenders' credit risk to CDS sellers, increasing lenders' credit supply to borrowers, and the influence of CDS on the bond markets. Our study adds to the literature by studying the consequences of CDS trading on firms' operations. In other words, we examine if and how CDS trading affects firms' IT strategies. Our empirical findings support extending the impact of CDS on firms' strategies and operations—IT investment in the current research. Moreover, our subgroup analysis suggests that this impact differs across firms with different financial, technology, and stability profiles.

Our research thus provides a rich understanding of the circumstances under which the impact of CDS on IT investment is of greater significance. In summary, our research demonstrates how external financial innovations affect firms' internal decision-making, such as IT investment.

Finally, our study shed light on the information systems literature on the determinants of IT investment. Past literature emphasizes factors such as firm size and scope, governance patterns, and industrial characteristics that may affect firms' IT adoption. Information systems research already provides evidence that IT adoption and implementation are of high cost and risk and examined the effect of firms' financial status (e.g., financial slack) on IT investment. However, given that financial innovations aiming to mitigate risks may play a role in influencing firms' IT strategies, there is a limited understanding of how financial innovations may affect IT investment. Our study introduces factors related to financial innovations that may exert effects on firms' IT adoption. In particular, our empirical analysis finds significant support for the impact of CDS trading on IT investment. Furthermore, the test of the mediation effect of credit risk and the subgroup analyses enrich the information system literature by contextualizing such an impact. In summary, our research contributes to the IS literature by linking financial innovations and IT investment and testing the link under different contexts.

1.8.2 Managerial Implications

Our study also has significant practical implications. Practitioners need to understand that the decision-making of enterprise IT investment depends not only on internal factors such as senior management support, IT governance mode, and business processes, but also on external forces, such as financial innovations in the market that may affect firms' financial status such as their exposure to credit risk. From a strategic point of view, this discovery is extremely important because by comprehensively understanding how enterprise IT strategies are made, senior managers can actively observe financial market dynamics and mobilize knowledge, technology, and resources to improve operational efficiency when opportunities come. In particular, our research points out that managers may need to understand how new financial instruments may change the financial fundamentals of their firms, which in turn influence their strategic decisions.

Our research also suggests that managers will need to assess different dimensions of the overall profiles of their organizations when implementing their IT strategies under the influence of financial innovations. In our research, under CDS trading, IT investment decisions are subject to the influence of firms' debt dependency, technology profile, and earning stability. Thus, managers need to pay attention to the interactions between innovations in the financial markets and the characteristics of their own firms when making strategic decisions related to IT. In particular, our research suggests that firms' credit risk is under such interaction effects, which in turn influence IT strategies that are costly and risky. In summary, our research suggests that managers need to take a holistic approach when assessing the optimal external and internal conditions for strategic IT investment.

Chapter 2

Optimal Distribution Strategy of SaaS Firms under Dual Distribution Channels

Abstract

SaaS is a web-based software delivery model licensed on a subscription basis and centrally managed. SaaS giants nowadays tend to diversify their products and distribution modes. I study the supply chain structure of one monopoly firm that provides both low-end and high-end SaaS. Low-end SaaS is standard and can be directly subscribed to online. High-end SaaS includes customized services, which require communication with customers and should be provided by an internal/external unit. For high-end SaaS distribution, a SaaS firm usually choose between a retailing division mode and an external reseller mode. This study explores and compares the two distribution modes of a monopoly SaaS provider. My analytical work reveals that several factors, including the external reseller's marketing advantage and customization cost, have crucial impacts on the SaaS firm's choice of the two distribution modes. The firm tend to adopt the retailing division mode in high-end SaaS distribution when the customization cost is high, or when customization cost is low and the external reseller's marketing advantage is small. I further study the impact of network effect by numerical analysis. I observe that, when the external retailer's marketing advantage is large, the network effect has an increasing positive impact on the profit of the retailing division mode first and then has an increasing negative impact. When the external retailer's marketing advantage is small, the network effect always has an increasing negative impact on the profit of the external reseller mode.

Keywords: *software as a service, supply chain structure, vertically differentiated market*

2.1 Introduction

Software as a service (SaaS), one of the most popular forms of cloud computing, is a web-based software delivery model licensed on a subscription basis and centrally managed. SaaS has been covering every aspect of business and life. Examples include *Apple iCloud*, *Dropbox*, *Gmail,* and *Salesforce* (Anselmi et al., 2014). In a B2B setting, enterprises can now enjoy cloud-based software services on a subscription basis via internet browsers for enterprise resource planning (ERP) or customer relationship management (CRM) purposes (Sun et al., 2008).

SaaS giants nowadays tend to diversify their products and delivery modes. Many choose to provide differentiated versions of one product through multiple distribution channels. These differentiated versions can be classified into two main categories, "standard" and "customized". For example, both *Salesforce* and *Dropbox* provide differentiated versions of their cloud services, e.g., Dropbox Basic and Dropbox Business. The version differences of *Salesforce* are shown in Figure 1. *Essential*s and *Professional* versions are what we call "standard" SaaS. Standard SaaS is designed to serve as many customers as possible. They are one-size-fits-all and have little customization. On the contrary, *Enterprise* and *Unlimited* versions are "customized" SaaS. For customized SaaS, software vendors provide customers with tailor-made services by extending and modifying standardized functions, catering to specific needs of certain industries and companies.

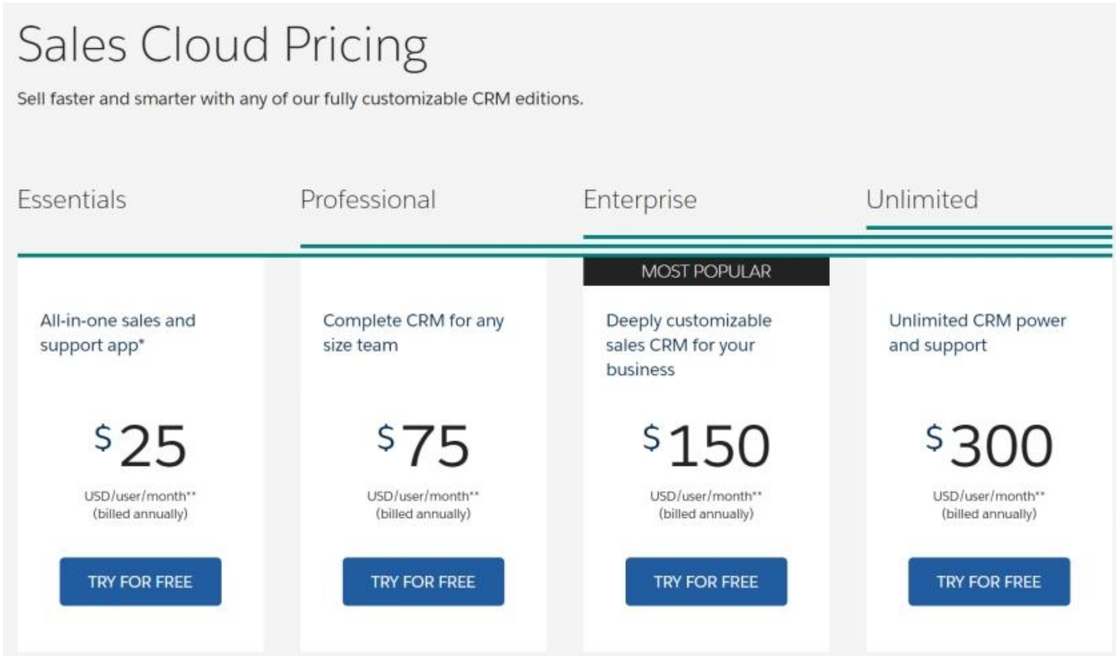

Figure 1. Package Prices of "Sales Cloud"

(Source: https://www.salesforce.com/products/sales-cloud/pricing/)

These two versions of SaaS are not delivered through an identical distribution channel. Standard versions can be directly ordered online from SaaS vendors' websites. This delivery model is referred to as "direct channel". Conversely, companies that demand customized services may need to contact software vendors' retailing division on purchasing, because communication in details and re-programming of products by developers are needed for tailor-made services. The corresponding distribution channel is referred to as "indirect channel".

The distribution mode of standard SaaS is identical across companies, as it is a common practice for SaaS companies to directly list standard products on their websites. Customers can directly subscribe standard versions on official websites. On the contrary, the delivery modes of customized SaaS products differ across companies. According to our observations, firms that offer customized SaaS mainly operate in two modes, retailing division mode and external reseller mode.

For retailing division mode, firms offer customized SaaS through its own retailing divisions. In other words, the SaaS firm sells all types of products independently. A typical example for retailing division mode can be *Salesforce*. Headquartered in San Francisco, U.S, *Salesforce* has 67 retail offices across 28 countries. It provides all kinds of customization services for customers directly through those retailing divisions distributed in different regions. Figure 2 shows an example of *Salesforce*'s retail office locations across US. Consumers can contact the nearest offices directly for customization purpose.

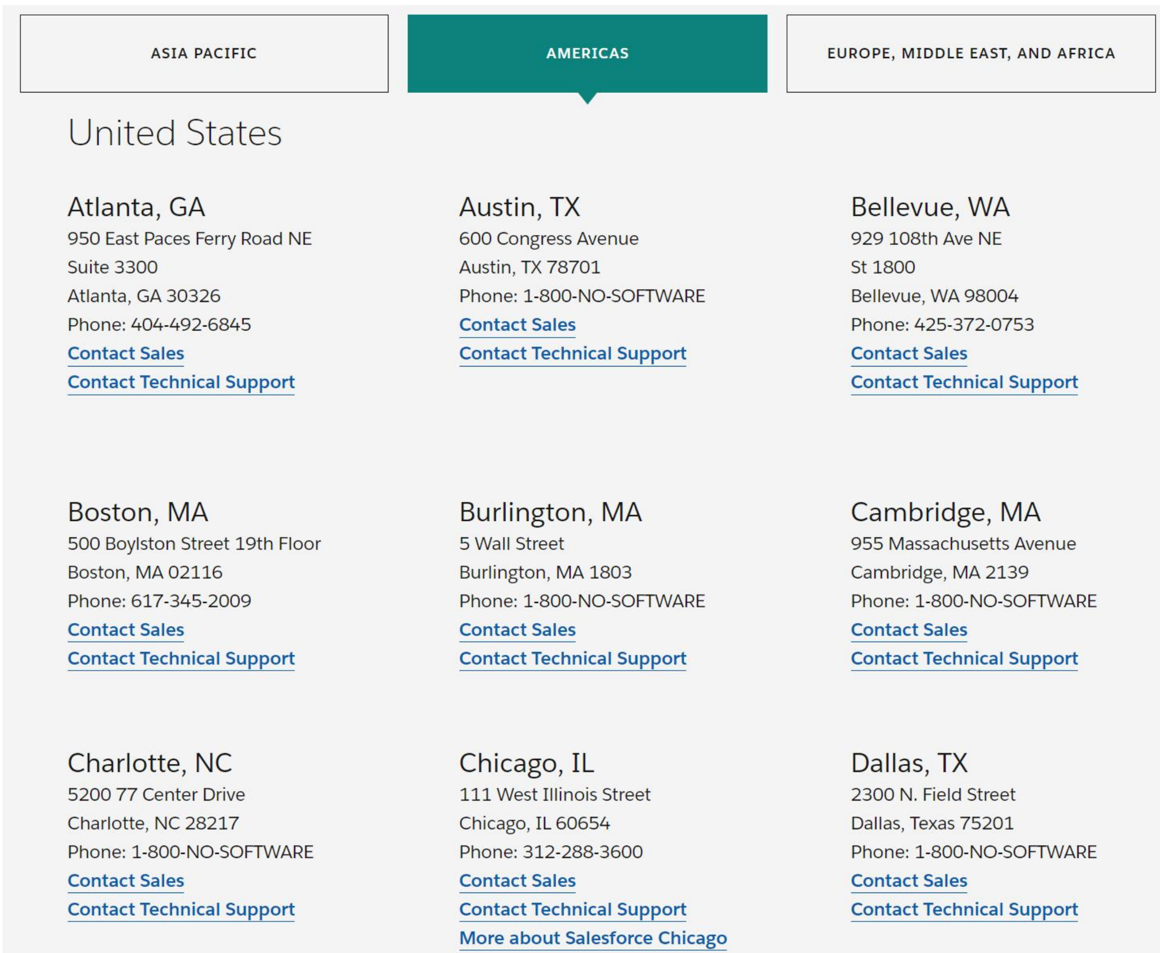

Figure 2. Salesforce's Office Locations in U.S

(Source: https://www.salesforce.com/ap/company/locations/)

For external reseller mode, SaaS firms outsource customization business to external resellers by collecting licensing fees while sell standard SaaS independently. One of the most typical companies is *Dropbox*. Instead of providing customization services independently, *Dropbox* chooses to cooperate with certified SaaS partners and had over 11,500 reselling partners worldwide by April 2020 (Kovar, 2020). After obtaining the license granted by *Dropbox*, these resellers can provide customized SaaS services to target customer groups. Accordingly, the resellers need to pay a licensing fee to *Dropbox* to obtain business qualification. Unlike *Salesforce*'s retailing division, which needs to meet the requirements of customization in all walks of life, *Dropbox*'s resellers are more differentiated in industry, region, and professional level. Figure 3 displays the reseller locater of Dropbox. With this filtering function, customers can filter the industry, region and specialization level corresponding to the reseller to select the most appropriate one.

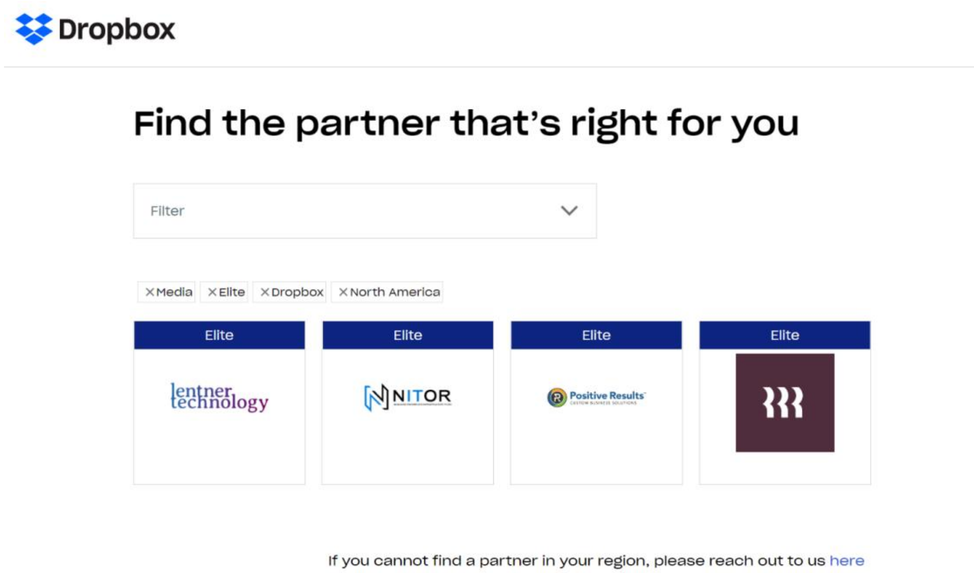

Figure 3. Dropbox Partner Locator

(Source: https://portal.dropboxpartners.com/s/locator?language=en_US)

For an enterprise that provides differentiated SaaS services, there are advantages and disadvantages in choosing between retailing division mode and reseller mode. Retailing division mode promotes the firm's chain operation, enables the company to have the final pricing power of all products, and increases the company's total profit. *Salesforce* operates in 90 cities, with 113 offices around the world, and had 73541 employees as of the 2022 fiscal year (Vailshery, 2022). *Dropbox* has only set up 12 offices in 8 countries with 2760 employees. Compared with rare offices, it cooperates with 11500 resellers worldwide (Kovar, 2020). For companies that adopt external reseller mode, the services provided by resellers are more professional and the customer needs are more matched. Resellers often focus on certain specific industries and have a higher understanding of the industry. Moreover, local resellers have a better understanding of local culture and can provide customization services with more regional characteristics. Nevertheless, in terms of pricing power, companies that adopt reseller mode can only charge licensing fees for authorized resellers but lose the final pricing power of customized SaaS.

Both models have advantages and disadvantages. In the trade-off between the two business models, we put forward our own research questions. 1. For a SaaS company that provides vertically differentiated products, which business model can achieve the greatest benefits? 2. What are the driving forces that affect the business model selection of the SaaS company?

We develop a theoretical model to study the research questions. In the model setting, we depict a monopoly SaaS company that sells vertically differentiated SaaS products, the standard product and customized product. For standard SaaS, the company directly sells it on official website. For customized SaaS, the company can choose from two modes, retailing division mode and external reseller mode. In retailing division mode, the company independently runs customization services. In this case, the SaaS company bears more operating and management costs. At the same time, it also has final pricing power for customized SaaS. In external reseller mode, the SaaS company cooperates with qualified resellers. It grants operating licenses to external resellers, who provide customization services for customers, while it only charges the resellers of licensing fees. In this case, the SaaS company reduces the operation and management costs. Meanwhile, external resellers give full play to their professional advantages to provide customers with more refined services. Correspondingly, the SaaS company gives up the final pricing right of customization products. We compare product prices, market share and total profits under the two business modes.

We find out that external resellers' marketing advantage and the customization cost of customized SaaS are two major forces that affect SaaS firms' choices of supply chain structure. When the customization cost is high or when the customization cost is low and marketing discount factor is high, the firm prefers retailing division mode. Specifically, for price comparison, when customization cost is low, the prices of standard SaaS and customized SaaS are higher when the firm chooses external reseller mode. For quantity comparison, when the customization cost is low, the demand of customized SaaS under external reseller mode is smaller than that under retailing division mode, while the demand of standard SaaS is higher under external reseller mode rather than that under retailing division mode. Moreover, we study the impact of network effect by numerical analysis. We observe that, when the external retailer's marketing advantage is large, the network effect has an increasing positive impact on retailing division mode first and then has an increasing negative impact on retailing division mode as it becomes stronger. When the external retailer's marketing advantage is not obvious, the network effect always has an increasing negative impact on external reseller mode.

The rest of this paper is organized as follows. In Section 2 we review the literature. In Section 3 we introduce the model setting and in Section 4 we present analyses of results. In Section 5 we further conduct an extension study. In Section 6 we conclude the findings and discuss about its implications and limitations.

2.2 Literature Review

Our study focuses on profit comparison of one SaaS company that sells vertically differentiated products under two distribution modes, retailing division mode and external reseller mode. When we review the past literature, we focus on supply chain structure studies and research on vertically differentiated markets.

There has been plenty of research focusing on supply chain structure, especially comparing centralized and decentralized supply chain. McGuire and Staelin (1983) study the impact of product substitution on channel structure adjustment. They point out that manufacturers prefer centralized channels when product substitutability is low. When products are competitive enough, manufacturers prefer decentralized channels. Xu et al. (2010) examine the choice of supply chain structure for a proprietary component manufacturer. Dan et al. (2012) analyze the optimal choice of retail service and price in centralized and decentralized dual channel supply chains using two-stage optimization and the Stackelberg game. The impact of retail services and customer fidelity to retail channels on manufacturers and retailers' pricing behavior is the focus of this study. Yang et al. (2015) propose customer return models under centralized and decentralized channel supply chains. Radhi and Zhang (2018) focus on the optimal pricing strategies of centralized and decentralized dual channel retailers with the same and cross channel revenue. Niu et al. (2019) compare the trade-off of multinational firms of their tax planning gains and supply chain decentralization loss. He et al. (2020) consider the deterioration characteristics of products under centralized and decentralized business models. Wang et al. (2022) examine how manufacturers and retailers achieve optimal decisions regarding delivery distance, acceptable return period, and pricing policy in centralized and decentralized dual channel supply chains. Pi et al. (2022) study the new function of free riding and explore how online customer perception affects decisions about product quality and retail service levels in e-commerce. In centralized and decentralized supply chains, they analyze and deduce the equilibrium product quality, retail service level and pricing strategy. Barman et al. (2022) assess the optimal strategies in the context of green manufacturing between maintaining the supply chain's profit maximization criterion with and without government subsidies. Additionally, the Stackelberg game evaluation method is used to compare the centralized versus decentralized marketing approaches.

Another stream of literature that relates to our study is vertically differentiated market. This stream of literature has a series of classic literature laying the foundation. After nearly half a century, the research on vertically differentiated market is still flourishing. For classic literature, one key study that studies product quality differentiation is by Mussa and Rosen (1978), who explore the quality decision of monopoly. Gabszewicz and Thisse (1980) study price competition in differentiated industry. Shaked and Sutton (1982) investigate how product differentiation relieves price competition. Based on their research, there is a continuous stream of recent literature covering a wider range of issues. We focus on reviewing pricing and distribution strategies of vertically differentiated products. For pricing strategies, Chipty and Witte (1998) study how customer knowledge affects the vertically differentiated childcare market's equilibrium market price and observable product quality. Kuksov and Lin (2010) analyze how competitive businesses' decisions about information sharing, product quality, and pricing interacted. Giannakas (2011) models consumer demand in vertically differentiated market. Li (2013) discusses the equilibrium outcomes for simultaneous and sequential price settings in a vertically differentiated market. Auer and Sauré (2017) develop a vertical innovation model in which companies sell products to consumers with differentiated tastes and study the dynamic entry strategies in this differentiated market. For distribution strategies, Gabszewicz and Wauthy (2003) propose joint purchase strategies of consumers for products of differentiated quality. Ren and Huang (2022) observe opaque selling scenarios in dealing with leftover inventories and study opaque selling strategies in a vertically differentiated market. He and Rui (2022) discuss the optimal design and profit of probabilistic selling in a vertically differentiated market.

We contribute to past literature from the following perspectives. First, we spot an early opportunity in studying vertically differentiated SaaS products. While SaaS has been intensively studied in recent information systems research, few studies have compared the distribution modes of SaaS. Our research fills the gap in information systems research on delivery modes of vertically differentiated SaaS. Second, while most studies in supply chain structure studies focus on physical goods, we add to the literature by studying information goods and conduct a comparative analysis of centralized and decentralized supply chain in vertically differentiated SaaS markets. Third, in SaaS studies, we point out that the matching degree of user needs of standard SaaS and the customization cost of customized SaaS will affect enterprise's choice of supply chain structure.

2.3 The Model

We consider a monopoly SaaS company that provides two differentiated products, standard SaaS and customized SaaS. Standard SaaS provides no customized service, and its price is relatively low. In the model setting, we define it as "low-end" product. In contrast, customized SaaS has customized services with relatively high prices, which we define as "high-end" product. p_L is demoted as the market price of standard SaaS and p_H as the market price of customized SaaS. Here "L" and "H" represent "low-end" and "high-end" respectively.

For a SaaS company that sells both high-end and low-end SaaS, it usually chooses between two distribution modes. One mode is called "retailing division mode". We define this mode as "DM". Another distribution mode is called "external reseller mode". We define this mode as "RM". We elaborate the two modes with the help of Figure 4.

Retailing Division Mode (DM): As shown in Figure 4, the company headquarters sells low-end SaaS directly on its website, as low-end SaaS is standardized, and consumers can purchase it on the official website without customized communication. Here "*H*" represents headquarters of SaaS company. The company sells high-end SaaS through its own retailing division. The revenue of retailing division belongs to the company, and the retailing division undertakes the corresponding customization tasks. For each unit of high-end products, the retail division makes customized improvements according to customer needs. A typical example is SaaS giant *Salesforce*, who manages 67 retail offices across 28 countries and undertake all customization services through these retailing divisions. One advantage of selling through retailing division is that companies have the final pricing power of high-end SaaS. However, the retailing division mode also has disadvantages. For a SaaS company, it cannot deeply dig into various market segments like external resellers. Therefore, the retailing division tends to exhibit a lower understanding of the local market and consumer preferences than the external reseller that specializes in a certain industry or region.

External Reseller Mode (RM): The company adopting external reseller mode sells low-end SaaS by itself, which is the same as *DM*. For high-end products, the company sells license to qualified external resellers as shown in Figure 4. These resellers have business qualifications, and because they are deeply engaged in certain specific fields and regions, it is easier for them to capture the specific needs of certain customers than the company's own retailing division. When an enterprise chooses external reseller to sell its high-end SaaS, it gives up the final pricing right of the product. On the other hand, by giving the right of customization and pricing to external resellers who have more experience in segmented markets, companies can enable consumers to obtain services closer to their needs. For example, *Dropbox* classifies external resellers according to region, industry, and partner tier. Customers can select their corresponding regions and industries to obtain more professional and refined services. Therefore, for the high-end product business, *Dropbox* only collects licensing fees from external resellers, and the sales profits will be obtained by external resellers themselves.

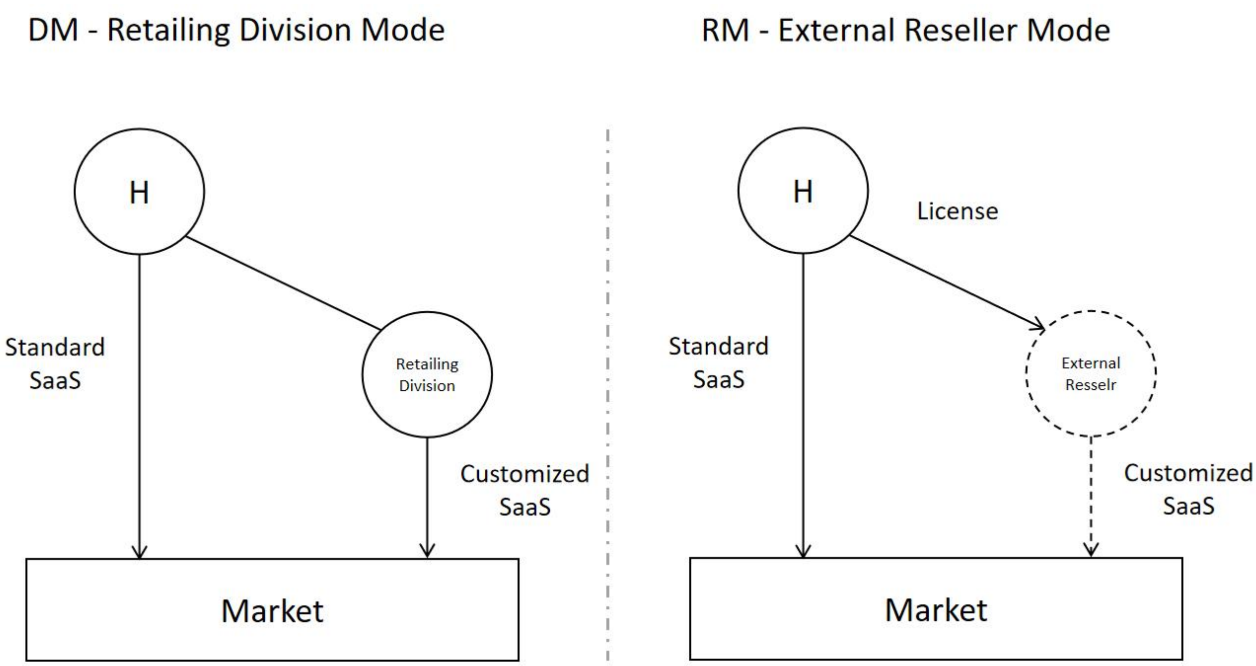

Figure 4. Distribution Mode

For consumers, as mentioned above, they have their own valuation v, that is uniformly distributed in the range [0, 1] towards the commodities. For consumers who purchase standard SaaS, they do not enjoy the tailor-made benefit, and in turn suffer from an unfit cost of valuation, which is denoted by the discount factor δ that ranges between 0 to 1. Conversely, for customers who purchase high-end SaaS, i. e. customized SaaS, of which made-to-measure services are provided, they bear a customization cost c in exchange for a better fit of use. Another discount factor that we introduce is the marketing discount factor θ. We note that retailing divisions are directly operated by the company, while resellers are independently operated. A SaaS company specializing in SaaS technology is often unable to surpass external resellers in the refinement of customized services. External resellers are often engaged in certain specific industries and deeply rooted in certain regions. For user requirements, external resellers can match to the largest extent. Therefore, external resellers have their own unique marketing advantage on customized services. This marketing discount factor depicts the unique competitiveness of external resellers.

Below we summarize the notations in Table 1:

Table 1. Notation Summary

Notation	Meaning
RM	External reseller mode
DM	Retailing division mode
r	External reseller
p_H	Price for high-end product under indirect channel
p_L	Price for low-end product under direct channel
w	Licensing fee
δ	Valuation discount factor for standard products, $\delta \in (0,1)$
θ	Marketing discount factor, $\theta \in (0,1)$
c	Customization cost under retailing channel
v	Customers' valuation towards services
γ	Network effect intensity

We first discuss retailing division mode.

2.3.1 Retailing Division Mode (DM)

In a monopolized market, a company provides customers with low-end and high-end SaaS products. Low-end products can be purchased directly from the company's website. High-end products are customized and delivered by the retailing division after communicating with customers. Customers in the market can choose either low-end or high-end product or do not use SaaS.

We begin the analysis with customers' utility function. For customers who purchase low-end products, following Li et al. (2018)'s work, we derive the utility function as follows:

$$U_L^{DM} = \delta\theta v^{DM} - p_L^{DM} \tag{1}$$

The utility of a low-end product buyer is equal to product's valuation minus the price. Because it is a standardized product, a mismatch cost δ is added to the valuation. θ here refers to mismatches caused by SaaS company's lack of understanding of specific regions and industry segments.

On the other side, customers who purchase high-end products have the utility function as follows:

$$U_H^{DM} = \theta v^{DM} - p_H^{DM} - c \tag{2}$$

For high-end customers, the marketing discount factor θ still exists, as retailing divisions are not better than external resellers at customization services. However, the customization mismatch cost δ can be removed.

The margin that customers are indifferent of between buying nothing and consuming through standard SaaS channel is $v_L^{DM} = \frac{p_L^{DM}}{\delta\theta}$ by letting equation $(1) = 0$. The margin that consumers are indifferent between standard SaaS and customized SaaS is thus $v_H^{DM} = \frac{p_H^{DM}+c-p_L^{DM}}{\theta(1-\delta)}$ by letting equation $(1) = (2)$. The demands in the two channels are expressed as $D_L^{DM} = v_H^{DM} - v_L^{DM} = \frac{p_H^{DM}+c-p_L^{DM}}{\theta(1-\delta)} - \frac{p_L^{DM}}{\delta\theta}$ and $D_H^{DM} = 1 - v_H^{DM} = 1 - \frac{p_H^{DM}+c-p_L^{DM}}{\theta(1-\delta)}$. In Figure 5, we illustrate the market segmentation under the mixed channel situation.

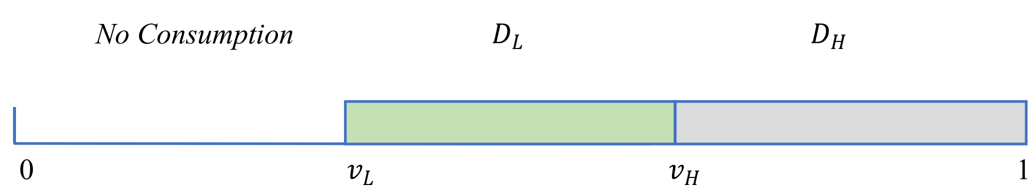

Figure 5. Market Segmentation under Mixed Distribution Channels

For a firm with retailing division, the objective profit function is thus described in equation (3):

$$\pi^{DM} = p_L^{DM} D_L^{DM} + p_H^{DM} D_H^{DM} \tag{3}$$

The total profit π^{DM} is derived from two channels, the direct and indirect channel. $p_L^{DM} D_L^{DM}$ indicates profit from direct channel. The company's benefit from the standardized products sold through the direct distribution channel can be expressed by multiplying the product price p_L^{DM} by the quantity D_L^{DM}. By comparison, $p_H^{DM} D_H^{DM}$ indicates profit from indirect channel. For the company, selling customized products also generates costs. The retailing division needs to communicate with customers and reprogram the existing standardized products according to their specific needs. Therefore, for each unit of customized SaaS products sold, the company will also generate corresponding customization cost c. Adding profits from both channels, we get total profit π^{DM} for the company. In other words, $\pi^{DM} = p_L^{DM} D_L^{DM} + p_H^{DM} D_H^{DM} = \frac{-\delta(c-p_H^{DM})(c+(-1+\delta)\theta+p_H^{DM})-2\delta p_H^{DM} p_L^{DM}+(p_L^{DM})^2}{(-1+\delta)\delta\theta}$.

To derive the optimal prices, we take derivatives of π^{DM} with respect to p_L^{DM}. The partial derivative function is $\frac{\partial(\pi^{DM})}{\partial(p_L^{DM})} = \frac{-2\delta p_H^{DM}+2p_L^{DM}}{(-1+\delta)\delta\theta}$ (4). Similarly, we take derivatives of π^{DM} with respect to p_H^{DM}. The partial derivative function is $\frac{\partial(\pi^{DM})}{\partial(p_H^{DM})} = \frac{-\delta(c-p_H^{DM})+\delta(c+(-1+\delta)\theta+p_H^{DM})-2\delta p_L^{DM}}{(-1+\delta)\delta\theta}$ (5). We let $(4) = (5) = 0$. Based on the simultaneous equations, we get optimal $p_L^{DM} = \frac{\delta\theta}{2}$ and $p_H^{DM} = \frac{\theta}{2}$.

We substitute p_L^{DM} and p_H^{DM} into $D_L^{DM} = v_H^{DM} - v_L^{DM} = \frac{p_H^{DM}+c-p_L^{DM}}{\theta(1-\delta)} - \frac{p_L^{DM}}{\delta\theta}$ and $D_H^{DM} = 1 - v_H^{DM} = 1 - \frac{p_H^{DM}+c-p_L^{DM}}{\theta(1-\delta)}$. We get optimal $D_L^{DM} = \frac{c}{\theta-\delta\theta}$ and $D_H^{DM} = \frac{1}{2} + \frac{c}{(-1+\delta)\theta}$.

Finally, we get optimal $\pi^{DM} = \frac{\theta}{4} + c(-1 + \frac{c}{\theta-\delta\theta})$.

Below we summarize the optimal outcomes of retailing division mode in Table 2.

Table 2: Optimal Outcomes for a Firm with a Retailing Division

$$p_L^{DM} = \frac{\delta\theta}{2}$$

$$p_H^{DM} = \frac{\theta}{2}$$

$$D_L^{DM} = \frac{c}{\theta - \delta\theta}$$

$$D_H^{DM} = \frac{1}{2} + \frac{c}{(-1+\delta)\theta}$$

$$\pi^{DM} = \frac{\theta}{4} + c(-1 + \frac{c}{\theta-\delta\theta})$$

2.3.2 External Reseller Mode (RM)

In reseller mode, the company still directly sells standard SaaS products to customers. However, for customized SaaS, the company sells license to an external reseller. At this point, if customers want to purchase customized products, they will directly contact the external reseller. The external reseller has the customization right and technology. It communicates directly with customers and customizes products for customers.

In this scenario, for customers who purchase low-end products, their utility function is as follows:

$$U_L^{RM} = \delta\theta v^{RM} - p_L^{RM} \tag{6}$$

For customers who purchase high-end products, their utility function is as follows:

$$U_H^{RM} = v^{RM} - p_H^{RM} - c \tag{7}$$

We can note that in this case, external reseller can meet the customized needs of consumers to the greatest extent because it is deeply involved in industries and regions. Therefore, we do not give any discount the valuation.

Similarly, as the firm is also a monopoly in its market, the market segmentation is the same as Figure 5. The margin that customers are indifferent of between buying nothing and consuming through standard SaaS channel is $v_L^{RM} = \frac{p_L^{RM}}{\delta\theta}$ by letting equation $(6) = 0$. The margin that consumers are indifferent between standard SaaS and customized SaaS is thus $v_H^{RM} = \frac{p_H^{RM}+c-p_L^{RM}}{1-\delta\theta}$ by letting equation $(6) = (7)$. The demands in the two channels are expressed as $D_L^{RM} = v_H^{RM} - v_L^{RM} = \frac{p_H^{RM}+c-p_L^{RM}}{1-\delta\theta} - \frac{p_L^{RM}}{\delta\theta}$ and $D_H^{RM} = 1 - v_H^{RM} = 1 - \frac{p_H^{RM}+c-p_L^{RM}}{1-\delta\theta}$.

For a firm with an external reseller, the objective profit function is thus described in equation (8):

$$\pi^{RM} = p_L^{RM} D_L^{RM} + w D_H^{RM} \tag{8}$$

The total profit is still generated from both direct and indirect channels. The direct channel is for the company to sell standardized products, and the expression formula is still price times quantity, $p_L^{RM} D_L^{RM}$. The profits brought by indirect channels are different from those of the retailing division. In this case, SaaS company authorizes the technology to external resellers that specialize in a certain field or deeply cultivate a certain region. Therefore, for SaaS companies, the benefit of indirect channels is the sales volume multiplied by the licensing fee, w.

Currently, the external reseller also becomes a market participant and has flexible customization pricing power. We define the objective profit function of external reseller as equation (9):

$$\pi_r^{RM} = (p_H^{RM} - w)D_H^{RM} \tag{9}$$

For this reseller, its profit is derived from the selling price of high-end products p_H^{RM}, minus the licensing fee it pays to SaaS company w, and then multiplied by the sales volume D_H^{RM}.

In calculation, $\pi^{RM} = p_L^{RM} D_L^{RM} + wD_H^{RM} = \frac{w\delta\theta(-1+c+\delta\theta+p_H^{RM})-\delta\theta(c+w+p_H^{RM})p_L^{RM}+(p_L^{RM})^2}{\delta\theta(-1+\delta\theta)}$ and $\pi_r^{RM} = (p_H^{RM} - w)D_H^{RM} = \frac{(-w+p_H)(-1+c+\delta\theta+p_H-p_L)}{-1+\delta\theta}$.

To derive the optimal prices, we take derivatives of π^{RM} with respect to p_L^{RM}. The partial derivative function is $\frac{\partial(\pi^{RM})}{\partial(p_L^{RM})} = \frac{-\delta\theta(c+w+p_H)+2p_L}{\delta\theta(-1+\delta\theta)}$ (10). Similarly, we take derivatives of π_r^{RM} with respect to p_H^{RM}. The partial derivative function is $\frac{\partial(\pi_r^{RM})}{\partial(p_H^{RM})} = \frac{(-w+p_H^{RM})(-1+c+\delta\theta+p_H^{RM}-p_L^{RM})}{-1+\delta\theta}$ (11). Moreover, we take partial derivatives of π^{RM} with respect to w. $\frac{\partial(\pi^{RM})}{\partial(w)} = \frac{8-8c+\delta^2\theta^2-2w(8+\delta\theta)}{(-4+\delta\theta)^2}$ (12). We let $(12) = 0$, and get optimal $w = \frac{8-8c+\delta^2\theta^2}{16+2\delta\theta}$.

We substitute $w = \frac{8-8c+\delta^2\theta^2}{16+2\delta\theta}$ into (10) and (11), and then let $(10) = (11) = 0$. Based on the simultaneous equations, we get optimal $p_L^{RM} = \frac{\delta\theta(10-2c-\delta\theta)}{2(8+\delta\theta)}$ and $p_H^{RM} = 3 - c - \frac{\delta\theta}{2} + \frac{2(-9+c)}{8+\delta\theta}$.

We substitute p_L^{RM} and p_H^{RM} into $D_L^{RM} = v_H^{RM} - v_L^{RM} = \frac{p_H^{RM}+c-p_L^{RM}}{1-\delta\theta} - \frac{p_L^{RM}}{\delta\theta}$ and $D_H^{RM} = 1 - v_H^{RM} = 1 - \frac{p_H^{RM}+c-p_L^{RM}}{1-\delta\theta}$. We get optimal $D_L^{DM} = \frac{1}{6}(3 - \frac{2c}{-1+\delta\theta} + \frac{2(-9+c)}{8+\delta\theta})$ and $D_H^{DM} = \frac{(2+\delta\theta)(-1+c+\delta\theta)}{(-1+\delta\theta)(8+\delta\theta)}$.

Finally, we get optimal $\pi^{RM} = \frac{\delta\theta}{4} - \frac{(-1+c+\delta\theta)^2}{(-1+\delta\theta)(8+\delta\theta)}$.

Below we summarize the optimal outcomes of external reseller mode in Table 3.

Table 3: Optimal Outcomes for a Firm with an External Reseller

$$w = \frac{8 - 8c + \delta^2\theta^2}{16 + 2\delta\theta}$$

$$p_L^{RM} = \frac{\delta\theta(10-2c-\delta\theta)}{2(8+\delta\theta)}$$

$$p_H^{RM} = 3 - c - \frac{\delta\theta}{2} + \frac{2(-9 + c)}{8 + \delta\theta}$$

$$D_L^{RM} = \frac{1}{6}(3 - \frac{2c}{-1 + \delta\theta} + \frac{2(-9 + c)}{8 + \delta\theta})$$

$$D_H^{RM} = \frac{(2 + \delta\,\theta)\,(-1 + c + \delta\,\theta)}{(-1 + \delta\,\theta)\,(8 + \delta\,\theta)}$$

$$\pi^{RM} = \frac{\delta\theta}{4} - \frac{(-1 + c + \delta\theta)^2}{(-1 + \delta\theta)(8 + \delta\theta)}$$

2.4 Outcome Analyses

2.4.1 Analysis of Prices

To explain the intuition behind the optimal strategies, we first compare the prices in terms of p_H and p_L between RM and DM, respectively. Define $c_1 = \frac{12-8\theta-2\delta\theta-\delta\theta^2-\delta^2\theta^2}{12+2\delta\theta}$ and $c_2 = 1 - \delta\theta$. We summarize the comparison results in Proposition 1.

Proposition 1.

a. *(Customized Price Comparison)*. $p_H^{RM} > p_H^{DM}$ when $0 < c < c_1$.

b. *(Standard Price Comparison)*. $p_L^{RM} > p_L^{DM}$ when $0 < c < c_2$.

Proposition 1 indicates that, when customization cost c is low, the prices of standard SaaS and customized SaaS are higher under *RM*. We start the analysis by price of customized SaaS. When the customization cost c is low, the firm can provide high-value customized SaaS at a remarkably low cost. Therefore, the firm mainly relies on the customized SaaS for profits. Since the retailer under *RM* has marketing advantage, it has the incentives to increase the retailing price of customized SaaS, which results in that the retailing price of customized SaaS is higher than that under *DM*. Correspondingly, the retailing price of standard SaaS will be higher under *RM*. In contrast, when the customization cost c is high, the firm may focus more on the standard SaaS. To cover the high cost for customized SaaS, the firm will increase the retailing price of customized SaaS under *DM*. While under *RM*, the retailer has little incentives to increase the retailing price because it will lose a significant amount of market share by doing that. Therefore, the retailing price of customized SaaS under *DM* is higher than that under *RM* when the customization cost is high. Aware of this, the firm will also set a lower price for standard SaaS to maintain a certain market share.

2.4.2 Analysis of Quantity

In this section, we further compare the demands in terms of D_H and D_L between RM and DM, respectively. Define $c_3 = \frac{-4\theta+4\delta\theta+5\delta\theta^2-5\delta^2\theta^2-\delta^2\theta^3+\delta^3\theta^3}{-16+4\theta+10\delta\theta+2\delta\theta^2}$ and $c_4 = \frac{-2\theta+2\delta\theta+\delta\theta^2-\delta^2\theta^2+\delta^2\theta^3-\delta^3\theta^3}{-16+6\theta+8\delta\theta+2\delta^2\theta^2}$. We can summarize the comparison results in Proposition 2.

Proposition 2.

a. *(Customized Quantity Comparison).* $D_H^{RM} < D_H^{DM}$ when $0 < c < c_3$.

b. *(Standard Quantity Comparison).* $D_L^{RM} > D_L^{DM}$ when $0 < c < c_4$.

Proposition 2 indicates that, when the customization cost c is low, the demand of customized SaaS under *RM* is smaller than that under *DM*, while the demand of standard SaaS is higher under *RM* than that under *DM*. From the findings in Proposition 1, when the customization cost c is low, the retailing price of customized SaaS is higher under *RM*, which will result in a lower demand. Interestingly, we find that, when the customization cost c is low, even when the retailing price of standard SaaS is higher under *RM*, the demand of demand of standard SaaS is higher under *RM*. The possible reason for this result may be the high retailing price of customized SaaS under *RM*. As we explained earlier, one of the reasons why an external retailer is motivated to increase the retailing price of customized SaaS is that it has marketing advantages. Another reason for an external reseller to set a high retailing price is the high licensing fee. It is worth noting that the company's licensing fee decision is negatively related to customization costs c. When c is small, the licensing fee w will be high, which also urges the external retailer to increase the retailing price to make up for the high purchasing cost. Because the retailing price of customized SaaS is so high, the market share of customized SaaS under *RM* will be low, which is conducive to the market share of standard SaaS. Therefore, even when the retailing price of standard SaaS is higher under *RM*, the demand of standard SaaS is higher under *RM* because the retailing price for customized SaaS under *RM* is too high.

2.4.3 Analysis of Profit

Finally, we compare the equlibrium profits between RM and DM. Define $\theta_1 = -\frac{2(-2+\delta)}{(-1+\delta)\delta} + 2\sqrt{-\frac{-4+3\delta}{(-1+\delta)^2\delta^2}}$, $c_5 = \frac{-6\theta+6\delta\theta+5\delta\theta^2-5\delta^2\theta^2+\delta^2\theta^3-\delta^3\theta^3}{2(-8+\theta+6\delta\theta+\delta^2\theta^2)} - \frac{1}{2}\sqrt{\frac{32\theta-32\delta\theta-32\theta^2-28\delta\theta^2+60\delta^2\theta^2+8\theta^3+36\delta\theta^3-12\delta^2\theta^3-32\delta^3\theta^3-7\delta\theta^4-3\delta^2\theta^4+7\delta^3\theta^4+3\delta^4\theta^4-\delta^2\theta^5-\delta^3\theta^5+\delta^4\theta^5+\delta^5\theta^5}{(-8+\theta+6\delta\theta+\delta^2\theta^2)^2}}$, $c_6 = \frac{-6\theta+6\delta\theta+5\delta\theta^2-5\delta^2\theta^2+\delta^2\theta^3-\delta^3\theta^3}{2(-8+\theta+6\delta\theta+\delta^2\theta^2)} + \frac{1}{2}\sqrt{\frac{32\theta-32\delta\theta-32\theta^2-28\delta\theta^2+60\delta^2\theta^2+8\theta^3+36\delta\theta^3-12\delta^2\theta^3-32\delta^3\theta^3-7\delta\theta^4-3\delta^2\theta^4+7\delta^3\theta^4+3\delta^4\theta^4-\delta^2\theta^5-\delta^3\theta^5+\delta^4\theta^5+\delta^5\theta^5}{(-8+\theta+6\delta\theta+\delta^2\theta^2)^2}}$.

We summarize the findings in Proposition 3.

Proposition 3. *(Profit Comparison)*. When $c_6 < c < 1$; or $0 < c < c_5$ and $\theta_1 < \theta < 1$, we have $\pi^{RM} < \pi^{DM}$.

Proposition 3 indicates that, the firm's preference over *RM* or *DM* depends on the customization cost c and the marketing discount factor θ. More specifically, when the customization cost is high or when the customization cost is low and marketing discount factor is high, the firm prefers *DM*. We first focus on the case where the customization cost is high. When the customization cost is high, the company mainly relies on standard SaaS to obtain profits, and the external retailer's marketing advantage is weakened to a certain extent. If the firm chooses *DM*, it can have the final pricing power of the customized SaaS. By doing that, the firm can ensure considerable profits from standard SaaS by avoiding the blind competition. Therefore, the firm would benefit from *DM*. We then turn to the second case where the customization cost is low and marketing discount factor is high. As customization cost is low, compared with standard SaaS, customized SaaS may generate more profits, and the company will focus more on the profits of customized SaaS. When the marketing discount factor is high, external resellers do not have major marketing advantages, nor can they significantly improve customer utility. Therefore, the company may seek to maintain the final pricing power, as it may be able to maintain all profits. On the contrary, when the marketing discount factor is low, external resellers have large marketing advantages, which can significantly improve the value of customized SaaS. In this case, *RM* may be beneficial to the company, as the licensing fee can generate substantial profits.

2.5 Extension: Network Effect

We consider the impact of network effect in the long run. Because consumers can benefit from the increasing trading transparency, data efficiency and market comprehensiveness brought by network effect as the number of consumers of one application inflates, they will in turn increase their valuation over this application. An example may be *Salesforce's* shared database, where the customers can anonymize and share their data with all other *Salesforce's* customers and depict a whole picture of the economy together. Following Cheng and Tang (2010)'s work, we introduce the network effect intensity γ to our model, which represents how much each addition to the number of buyers boosts the software's perceived value. It thus expands the total market size by $\gamma(D_H + D_L)$. We introduce the network effect on two strategies respectively.

2.5.1 Retailing Division Mode with Network Effect

The customers' utility under customized channel is still $U_H^{DM} = \theta v^{DM} - p_H^{DM} - c$ and under standard channel is $U_L^{DM} = \delta\theta v^{DM} - p_L^{DM}$ like previous case. Due to the network effect, the market size and segmentation are now depicted in Figure 6.

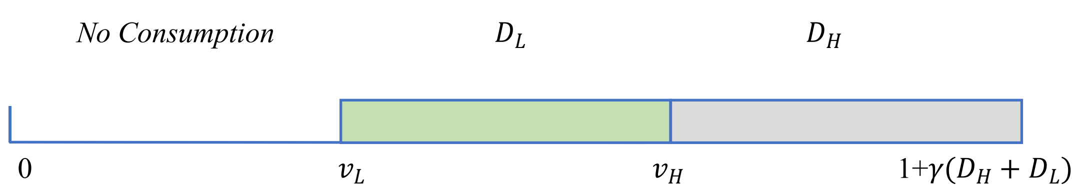

Figure 6. Market Segmentation under Mixed Distribution Channels with Network Effect

The indifferent margins are still $v_H^{DM} = \frac{p_H^{DM}+c-p_L^{DM}}{\theta(1-\delta)}$ and $v_L^{DM} = \frac{p_L^{DM}}{\delta\theta}$ respectively. The demands in the two channels are expressed as $D_L^{DM} = v_H^{DM} - v_L^{DM} = \frac{p_H^{DM}+c-p_L^{DM}}{\theta(1-\delta)} - \frac{p_L^{DM}}{\delta\theta}$ and $D_H^{DM} = \frac{1+\gamma D_L^{DM} - \frac{p_H^{DM}+c-p_L^{DM}}{\theta(1-\delta)}}{1-\gamma} =$

$\frac{\delta(c(-1+\gamma)+\theta-\delta\theta+(-1+\gamma)p_H^{DM})+(-\gamma+\delta)p_L^{DM}}{(-1+\gamma)(-1+\delta)\delta\theta}$. The profit function is still $\pi^{DM} = p_L^{DM}D_L^{DM} + p_H^{DM}D_H^{DM} = \frac{(-1+\gamma)\delta(p_H^{DM})^2+(-1+\gamma)p_L^{DM}(-c\delta+p_L^{DM})+p_H^{DM}(\delta(c(-1+\gamma)+\theta-\delta\theta)-(\gamma+(-2+\gamma)\delta)p_L^{DM})}{(-1+\gamma)(-1+\delta)\delta\theta}$.

We derive the optimal outcomes and summarize them in Table 4. *Proof.* Please see the Appendix.

Table 4: Optimal Outcomes for a Firm with a Retailing Division (Network Effect)

$$p_L^{DM} = \frac{\delta(c(-1+\gamma)\gamma+(\gamma+(-2+\gamma)\delta)\theta}{\gamma^2-(-2+\gamma)^2\delta}$$

$$p_H^{DM} = \frac{(1-\gamma)\delta(c(-2+\gamma)+2\theta)}{-\gamma^2+(-2+\gamma)^2\delta}$$

$$D_L^{DM} = \frac{c(\gamma+(-2+\gamma)\delta)+\gamma(-1+\delta)\theta}{(-1+\delta)(-\gamma^2+(-2+\gamma)^2\delta)\theta}$$

$$D_H^{DM} = \frac{\delta(2c(-1+\gamma)+(-2+\gamma)(-1+\delta)\theta)}{(1-\delta)(-\gamma^2+(-2+\gamma)^2\delta)\theta}$$

$$\pi^{DM} = \frac{\delta(c^2(-1+\gamma)+c(-2+\gamma)(-1+\delta)\theta+(-1+\delta)\theta^2)}{(-1+\delta)(-\gamma^2+(-2+\gamma)^2\delta)\theta}$$

2.5.2 External Reseller Mode with Network Effect

The customers' utility under customized channel is still $U_H^{RM} = v^{RM} - p_H^{RM} - c$ and under standard channel is $U_L^{RM} = \delta\theta v^{RM} - p_L^{RM}$ like previous case. The indifferent margins are still $v_H^{RM} = \frac{p_H^{RM}+c-p_L^{RM}}{1-\delta\theta}$ and $v_L^{RM} = \frac{p_L^{RM}}{\delta\theta}$ respectively. The demands in the two channels are expressed as $D_L^{RM} = v_H^{RM} - v_L^{RM} = \frac{p_H^{RM}+c-p_L^{RM}}{1-\delta\theta} - \frac{p_L^{RM}}{\delta\theta}$ and $D_H^{DM} = \frac{1+\gamma D_L - \frac{p_H^{RM}+c-p_L^{RM}}{1-\delta\theta}}{1-\gamma}$. The total profit function is still $\pi^{RM} = p_L^{RM}D_L^{RM} + wD_H^{RM} = \frac{-w\delta\theta(-1+c-c\gamma+\delta\theta)+(-1+\gamma)\delta\theta p_H^{RM}(w-p_H^{RM})+p_L^{RM}(-w\gamma+(c+w-c\gamma)\delta\theta+(-1+\gamma)p_L^{RM})}{(-1+\gamma)\delta\theta(-1+\delta\theta)}$ and the profit function for external reseller is $\pi_r^{RM} = (p_H^{RM} - w)D_H^{RM} = \frac{(w-p_H^{RM})(\delta\theta(-1+c-c\gamma+\delta\theta-(-1+\gamma)p_H^{RM})+(\gamma-\delta\theta)p_L^{RM})}{(-1+\gamma)\delta\theta(-1+\delta\theta)}$.

Below we summarize the optimal outcomes of external reseller mode in Table 5. *Proof.* Please see the Appendix.

Table 5: Optimal Outcomes for a Firm with an External Reseller (Network Effect)

$$w = -\frac{\delta\theta(8+2c(-4+\gamma)(-1+\gamma)^2+7(-2+\gamma)\gamma+2(-2+\gamma)\gamma\delta\theta+\delta^2\theta^2)}{-2\gamma^3+2(-2+\gamma)(4+(-7+\gamma)\gamma)\delta\theta-2\delta^2\theta^2}$$

$$p_L^{RM} = -\frac{(-1+\gamma)\delta\theta(2c\gamma^2+\delta\theta(-10+2c+\delta\theta)+\gamma(4-4c+5\delta\theta))}{-2\gamma^3+2(-2+\gamma)(4+(-7+\gamma)\gamma)\delta\theta-2\delta^2\theta^2}$$

$$p_H^{RM} = -\frac{2-2\delta\theta+c(-2+\gamma+\delta\theta)+\frac{(8+2c(-4+\gamma)(-1+\gamma)^2+7(-2+\gamma)\gamma+2(-2+\gamma)\gamma\delta\theta+\delta^2\theta^2)(\gamma^2+2(1+(-3+\gamma)\gamma)\delta\theta+\delta^2\theta^2)}{(-1+\gamma)(-2\gamma^3+2(-2+\gamma)(4+(-7+\gamma)\gamma)\delta\theta-2\delta^2\theta^2)}}{-4+3\gamma+\delta\theta}$$

$$D_L^{RM} = \frac{1}{6}\left(-\frac{3}{-1+\gamma}-\frac{2c}{-1+\delta\theta}-\frac{6(-2+\gamma)\gamma+2c\gamma(6+(-6+\gamma)\gamma)-2c\delta\theta+3(-3+\gamma)(-2+\gamma)\delta\theta}{\gamma^3-(-2+\gamma)(4+(-7+\gamma)\gamma)\delta\theta+\delta^2\theta^2}\right)$$

$$D_H^{RM} = \frac{1}{6}\left(-\frac{3}{-1+\gamma}-\frac{2c}{-1+\delta\theta}-\frac{6(-2+\gamma)\gamma+2c\gamma(6+(-6+\gamma)\gamma)-2c\delta\theta+3(-3+\gamma)(-2+\gamma)\delta\theta}{\gamma^3-(-2+\gamma)(4+(-7+\gamma)\gamma)\delta\theta+\delta^2\theta^2}\right)$$

$$\pi^{RM} = -\frac{\delta\theta(4c^2(-1+\gamma)^3+4c(-2+\gamma)(-1+\gamma)^2(-1+\delta\theta)+(-1+\delta\theta)((2+\delta\theta)^2+\gamma^2(5+4\delta\theta)-2\gamma(4+5\delta\theta)))}{4(-1+\gamma)(-1+\delta\theta)(\gamma^3-(-2+\gamma)(4+(-7+\gamma)\gamma)\delta\theta+\delta^2\theta^2)}$$

2.5.3 Profit Comparison

Because it is difficult to reach analytical results for profit comparison with network effect, we perform numerical analysis and plot out the most typical cases in Figure 7.

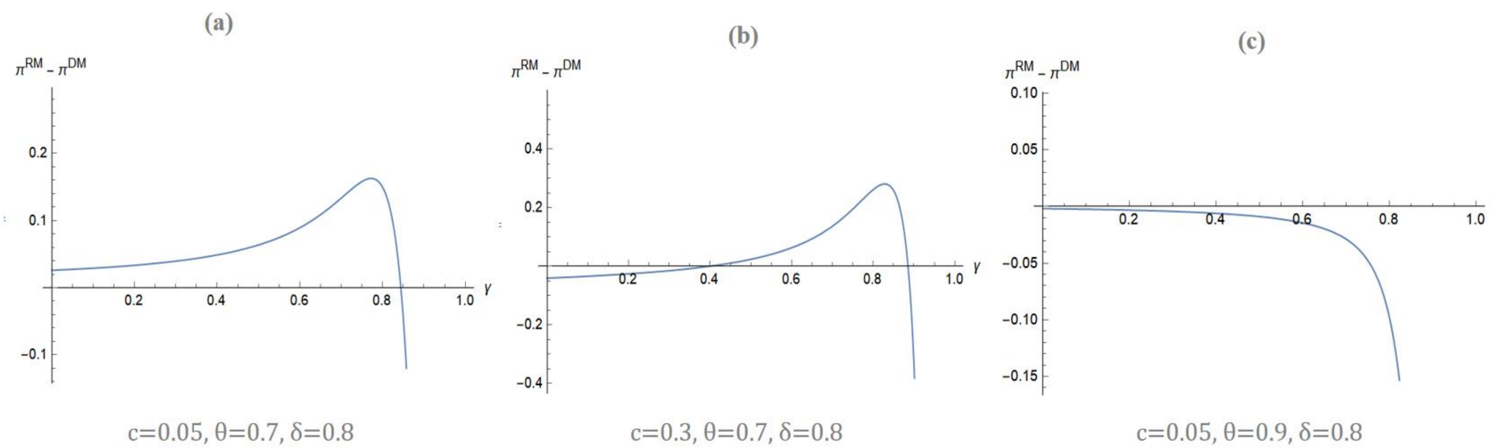

Figure 7. The Total Profit Difference between *RM* and *DM* with Network Effect

We observe that, when the external retailer's marketing advantage is large, the network effect has an increasing positive impact on *RM* first and then has an increasing negative impact on *RM* as it becomes stronger. We illustrate this finding with Figures 7(a) and 7(b). Figure 7(a) shows the profit difference between *RM* and *DM* when customization cost is low, and Figure 7(b) shows the profit difference between *RM* and *DM* when customization cost is high. When network effect is weak, the company's profit under *RM* will be higher with the increase of network effect, because external resellers have larger marketing advantages in this situation. Compared with *DM*, the demand for customized SaaS under *RM* will be larger, and the network effect will further increase demand for customized SaaS, thus increasing the overall profit of the SaaS firm. When the network effect is particularly strong, the market potential brought by network effect is considerable. The SaaS firm will prefer *DM*, because under *DM*, it has the pricing power of both high-end and low-end SaaS and thus obtains higher profits by price adjustments.

When the external retailer's marketing advantage is small, the network effect always has an increasing negative impact on *RM*, as shown in Figure 7(c). When θ is large, the external resellers do not have large marketing advantage, and the demand for customized SaaS cannot be greatly improved through external resellers. On the contrary, under *DM*, the SaaS firm can have the pricing power of both high-end and low-end SaaS and obtain all profits. With the increase of network effect, the firm will prefer *DM*.

2.6 Conclusions and Discussion

In this study, we mainly compare the profitability of two business modes of SaaS firms that provides vertically differentiated SaaS. The distribution modes of Standard SaaS are similar. Consumers can subscribe standard versions directly on the official website of SaaS companies, which is very convenient. On the contrary, we observe that SaaS giants mainly adopt two business modes for customized SaaS delivery. One type of delivery mode is called "retailing division mode". Firms that adopt this business mode deliver customized SaaS through their own retailing divisions. A typical example is *Salesforce* that operates 67 retailing offices across 28 countries. The retailing offices communicate and undertake customization services. Another type of delivery mode is called "external reseller mode". Firms that adopt this mode authorizes customization certification to qualified external resellers and charge licensing fees. The functions of external resellers are similar to those of retailing divisions. They communicate with customers independently and provide customers with various customized services. The difference is that at this time, SaaS companies can only obtain licensing fees from customized services, but they do not have pricing rights for high-end SaaS, and they cannot obtain sales profiles for high-end SaaS either. A typical example of this mode is *Dropbox*, who cooperate with more than 11,500 certified reselling SaaS partners. We would like to explore the tradeoff between the two business modes, and to know the considerations behind the enterprise's choice of either mode.

With the help of theoretical models, we describe a monopoly SaaS company that offers vertically differentiated SaaS products, including standard SaaS and customized SaaS. For standard SaaS, the company sells it directly on the official website. For customized SaaS, the company can choose between two modes, retailing division mode and external reseller mode. Under the retailing division mode, the company operates customized services independently. At the same time of higher operating costs, it has also obtained the final pricing right of customized products. Under the external reseller mode, the company cooperates with qualified dealers. It grants operating licenses to external distributors that provide customized services to customers, and only collects license fees from distributors. In this case, the SaaS company has reduced operating and management costs. Accordingly, the company gave up the final pricing right of customized products. We compare the product price, market share and total profit under the two business modes.

First, we find out that, when a SaaS company provides both standard and customized SaaS, its choice of business modes mainly depends on external resellers' marketing advantage and the customization cost. When the customization cost is high or when the customization cost is low and marketing discount factor is high, the SaaS firm prefers retailing division mode. For price comparison, when customization cost is low, the prices of standard SaaS and customized SaaS are higher when the firm chooses external reseller mode. For quantity comparison, when the customization cost is low, the demand of customized SaaS under external reseller mode is smaller than that under retailing division mode, while the demand of standard SaaS is higher under external reseller mode rather than that under retailing division mode. In the extension, we incorporate one typical feature of information goods, network effect, by expanding the total market size. We study the impact of network effect by numerical analysis. We observe that, when the external retailer's marketing advantage is large, the network effect has an increasing positive impact on retailing division mode first and then has an increasing negative impact on retailing division mode as it becomes stronger. When the external retailer's marketing advantage is small, the network effect always has an increasing negative impact on external reseller mode.

Theoretically, our study contributes to two streams of literature, supply chain structure and vertically differentiated market. First, supply chain structure is a field that has been extensively studied. Motivated by the reality of today's digital process, we add the topic of information goods represented by SaaS to existing literature. Vertically differentiated market is also a hot topic in supply chain research. Our research is based on two kinds of vertically differentiated products, high-end and low-end SaaS. We supplement several key determinants that affect the selection of the company's supply chain structure, namely, the marketing discount factor to user needs, and the customization cost of high-end SaaS. In addition, our study is a comparative study. In the model, we analyze both centralized and decentralized supply chain structures, and compare their profitability, product price and demand.

Our study also has practical implications. First, our research provides supply chain management ideas for SaaS companies. A sudden COVID-19 pandemic has not only seriously impacted people's daily life, but also greatly accelerated the digitization process of the whole society. The digital economy has become a beacon guiding the direction in the pandemic. Under this situation, the global SaaS market has ushered in development opportunities. With the further deepening and improvement of the SaaS market and the diversification of SaaS product categories, the discussion of the company's supply chain management model is applicable to every SaaS enterprise eager to grow. Secondly, our research on operation investment strategy is also of practical significance. For enterprises that provide vertically differentiated SaaS, choosing a business mode is a trade-off between comparative advantages. Retailing division mode is not conducive to SaaS firms providing the most refined customized SaaS. However, it is conducive to the chain operation of the SaaS firms. At the same time, the firm can obtain the final pricing power of high-end SaaS. On the contrary, authorizing external resellers to provide customized SaaS will make the company abandon the final pricing power of high-end SaaS. However, since external resellers focus on serving a certain region and industry, the higher matching of user needs is the unique competitiveness of the external reseller mode. In addition, our research has the long-term significance. One of the characteristics of information goods is that they have network effect. Our research shows that under the influence of network effect, marketing advantage of external resellers still affects the choice of firm's business modes.

Despite our contributions to the literature on SaaS enterprise distribution strategies, there are several limitations to our research that should be noted. First, our model assumes that the SaaS enterprise chooses between retailing division mode and external reseller mode without considering the potential effects of vertical restraints such as resale price maintenance (RPM), exclusive dealing, and exclusive territory. Future research could explore how the adoption of external retailing channels while imposing RPM or other vertical restraints could affect the conclusions drawn in our study. Second, our model only solves for the optimal distribution strategy for high-end SaaS, assuming that low-end SaaS is sold directly online at a fixed price. A more realistic model, on the other hand, would evaluate the optimal retail price as a function of the licensing fee, and then solve for the optimal licensing fee and retail price for low-quality services. Future research could explore this angle to provide a more comprehensive understanding of the distribution strategies of SaaS enterprises. Finally, while our model provides insights into the distribution strategies of a monopoly SaaS provider, it does not consider the impact of competition from other SaaS providers on the optimal distribution strategy. Future research could explore how competition affects the distribution strategies of SaaS enterprises and whether the conclusions drawn in our study hold in a more competitive market setting. In conclusion, while our study contributes to our understanding of the distribution strategies of SaaS enterprises, there are a number of areas where future research could expand on our findings and provide a deeper understanding of this crucial topic.

Chapter 3

Co-Opetition Strategy for Two-Sided Platforms in Vertically Differentiated Markets

Abstract

E-commerce giants, such as *Amazon*, have recently started linking products sold by their competitors on their platforms. This business strategy has been labeled “co-opetition,” which is a combination of cooperation and competition. This study examines such a strategy by developing a theoretical model in the e-commerce platform context. This model includes one small and one large co-opetiting firms, with each firm having its own online sales platform and market where products of vertically differentiated quality are being sold. Three types of cooperation strategies, namely, one-way cooperation (the large firm links the products of the small firm on its platform), two-way cooperation (both the small and large firms link the products of each other on their respective platforms), and non-cooperation (the small and large firms operate in two independent markets). Product quality differentiation emerges as a key factor that drives cooperation decision making. Relative to non-cooperation, two-way cooperation yields higher profit margins for both firms when the degree of quality differentiation between these firms is high. Finally, given that the current one-way cooperation prevents the small firm from paying a listing fee to the large firm, this type of cooperation is not to occur under the co-opetition setting.

Keywords: *co-opetition, vertically differentiated market, two-sided platform, e-commerce*

3.1 Introduction

A conventional platform includes a market that connects two groups of users, such as buyers to sellers and gamers to game developers (Farrell et al., 2018). These platforms serve primarily two functions, namely, matching and facilitating transactions between agents and improving the quality of these transactions (Mantena & Saha, 2012). Driven by profit incentives (Rochet and Tirole, 2006), these platforms, which operate across different industries such as software and payment card systems, have recently adopted a two-sided model where the demands of two interactive users are met by sellers through the platform (Parker et al., 2005; Lee et al., 2021). This model has three elements. First, no less than two groups of users are connected through the platform where they finish their transactions. Second, in a two-sided market, these groups are influenced by indirect network effects. One typical example of an attractive platform is an auction website. Third, a non-neutral price structure is usually adopted in a two-sided market. To increase trading volume, companies and platforms adopt price segmentation to enhance their pricing strategies.

Two-sided platforms are particularly attractive to many industries, especially following the recent explosion in the number of interactions between e-commerce and online consumers (Dou et al., 2020). A typical example of a two-sided platform is an e-commerce platform, such as Amazon and Alibaba, where individuals purchase products or services without the need to visit physical shops (Bigne et al., 2005). However, the network effect in two-sided markets make cooperation and competition inevitable. The collaboration among platforms sharing the same network can significantly benefit the welfare of customers. Specifically, by accessing a larger network scale, these platforms offer these customers a higher level of network effect utility, hence making these platforms more attractive to potential users (Mantena & Saha, 2012; Wang et al., 2022). For instance, some large e-commerce platforms, such as *Amazon* and *Walmart*, link similar products being offered by other retailers on their platforms. Specifically, *Amazon* displays similar products that are being sold by various sellers on the same page of its online shopping interface, thus reducing the time spent by customers in browsing across multiple pages and allowing them to compare products quickly.

As shown in Figure 1, searching for a book on *Amazon* would yield results that include the products sold by *Amazon* itself and other retailers. Clicking the link marked by the green circle (left pane) would lead to a new page (right pane) listing the same product sold by smaller sellers (for instance, *glenthebookseller*, as indicated by the red circle). This figure is a typical example of a "co-opetition" behavior in the platform (Walley, 2007). Specifically, *glenthebookseller* cooperates with Amazon in order to sell its product on such a large platform and simultaneously competes with *Amazon* in selling the same product.

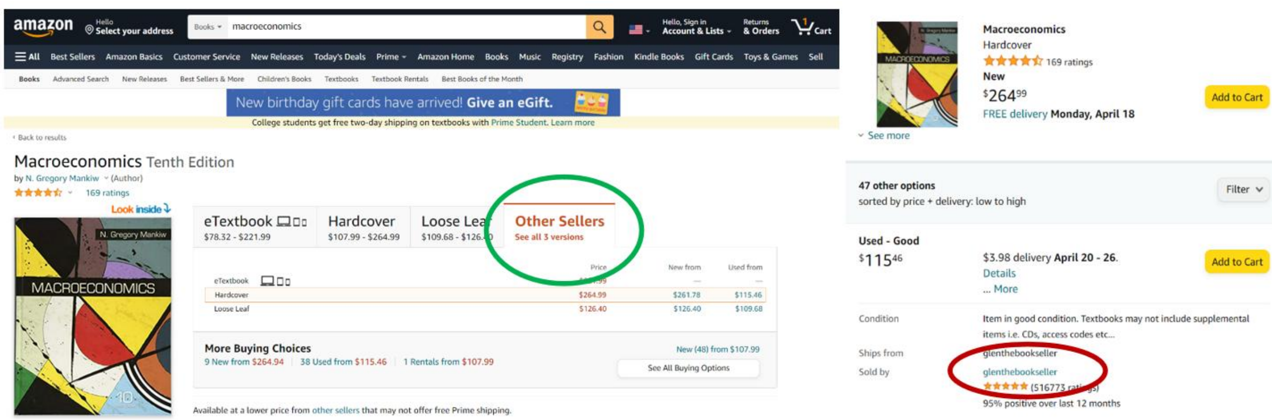

Figure 1. Interface of Amazon

Listing fees may also explain the co-opetition strategy adopted in Amazon. In the article "Amazon's Share" (2021), eMarketer reports that in 2020, *Amazon* has expanded its share of the digital advertising market in the United States to 10.3% (from 7.8% in the previous year) and increased its advertising revenue by 52.5% (equivalent to US $15.73 billion). This revenue includes the "listing fee" being charged by Amazon to its competitors. Specifically, *Amazon* connects its competitors to its own consumers by allowing them to list their products on its platform. Therefore, while generating additional profit (e.g., sales and listing fees) for online retailing platforms, co-opetition also introduces more competition, hence forming a tradeoff between competition and sales. In this case, this study attempts to answer two questions. First, would an e-seller receive any profit margin by offering its platform to its competitors to sell their products? Second, relative to operating independently, would two e-sellers receive higher profits when they use each other's platforms to sell their products?

To answer the above questions, this study builds a co-opetition model in the e-commerce platform context that involves a large firm and a small firm engaged in co-opetition. These firms are vertically differentiated in terms of the quality of their products and have their own markets and online platforms. Three cases are examined in this model. In the non-cooperation case, these firms choose to operate independently instead of cooperating. In the two-way cooperation case, these firms engage in co-opetition by including links to each other's products on their respective platforms, which would allow consumers to compare these products. Each firm also charges a listing fee to the other. In the one-way cooperation case, the small firm asks the large firm to post links to its products on its platform, but the large firm does not make the same request.

Product quality differentiation emerges as a key factor in the cooperation/co-opetition decision making of firms. Specifically, two-way cooperation yields higher profit margins for both firms when their products have sufficient variation in quality, and a higher product quality differentiation corresponds to a higher profit margin. Co-opetition also prevents the occurrence of one-way cooperation as the small firm is unable to pay a listing fee to the large firm.

The rest of this article is organized as follows. Section 2 reviews the related literature. Section 3 introduces the basic model settings. Section 4 analyzes the profit of firms. Section 5 investigates the one-way cooperation case. Section 6 concludes the paper.

3.2 Literature Review

This study focuses on the adoption of co-opetition strategies in vertically differentiated markets. Accordingly, two streams of related literature are reviewed as follows.

The first stream focuses on co-opetition in platforms. Walley (2007) defines co-opetition as "cooperative competition," where two companies compete and cooperate with each other simultaneously. Many companies have long engaged in this type of relationship, which similarly has gained praise from scholars. This concept has also been adopted in many emerging business paradigms, particularly online platforms. Bilbil (2018) takes *Booking*'s disclosure as a case study and explores tourism coopetition from the perspectives of both the agent and the industry. Thépot (2018) examines the relationship between consumer welfare and digital platform co-opetition. Dagnino et al. (2019) investigate the tension and connection in the digital innovation of firms in the co-opetition context. Liu (2019) evaluates the co-opetition behaviors of commercial banks and e-businesses and proposes some suggestions for enhancing their cooperation. Using 365 complementors' data from *Amazon,* Yoo et al. (2020) investigate the co-opetition ecosystem of the platform from a complementary perspective. Cohen and Zhang (2022) analyze the profit-sharing contracts of two competing platforms that introduce new joint services. Xu et al. (2022) focus on ride-hailing platforms with bundled channels and examine their profit contention.

The second stream focuses on vertically differentiated markets. Research on these markets face huge problems in obtaining information. Chipty and Witte (1998) evaluate how consumer information influence price and market equilibria by using a vertically differentiated childcare market as an example. Liu and Serfes (2005) examine the incomplete differential pricing problem in the presence of vertical differences and find that only those manufacturers that sell high-quality goods would willingly implement three-level differential pricing and obtain information when the cost of obtaining such information is below a critical value. Kuksov and Lin (2009) explore the interaction among pricing decisions, product quality, and information provision in vertically differentiated markets. Some researchers have also explored the competition among differentiated products. For instance, Lambertini and Tampieri (2012) model a vertically differentiated duopoly involving quantity-setting firms and find that the lower-quality firm takes lead in the model subgame. Li (2014) explore how price leadership works in a vertically differentiated market and compare the equilibria under sequential and simultaneous pricing strategies. The dynamic entry and exit strategies that have been recently used by firms in a vertically differentiated market have also received scholarly attention. Auer and Saure (2017) explore the quality asymmetry problems that emerge during sequential entry situations in vertically differentiated markets. Baron (2021) argues that threat of entry can actually sustain growth, stimulates the introduction of new products, and reduce prices in the market.

Although flourishing, recent studies on platform co-opetition have only focused on various emerging industries. To fill such gap, this study compares three co-opetition scenarios in two-sided platforms that involve e-commerce firms having their own platforms. This study also sets itself apart from the literature by studying the co-opetition behaviors of firms with vertically differentiated products. This work contributes to previous studies on vertically differentiated markets by discussing the co-opetition strategies adopted in e-commerce platforms and by underscoring how the decision making of firms hinges on product quality differentiation. Some operational insights for firms with vertically differentiated products are also provided.

3.3 The Model

Markets. With reference to Nan et al. (2020), this study explores a market in which a firm uses its own platform to sell a single type of product and buyers use the same platform to purchase the product. Two independent markets, denoted by market $i \in \{1, 2\}$, are considered in this scenario. These markets have a different consumer base or show asymmetry in their market size. Without loss of generality, market 1 is assumed to be larger than market 2. Following Liu et al. (2014), the asymmetry in market size is captured by adding consumer base discount factor $\eta \in (0, 1)$ to market 2.

Firms. Firm i acts as the monopolist of product i in its market and has its own sales platform. This firm produces product i with quality q_i that is sold at price p_i. Without loss of generality, the quality of product is normalized as 1, whereas product 2 has lower quality (*i.e.,* $0 < q_2 \leq q_1 \leq 1$).

Consumers. The consumers are uniformly distributed over the interval $[0,1]$ and demonstrate heterogeneity in their preference for purchasing product i. Such heterogeneity is captured using θ (*i.e.,* $\theta \sim U$) $[0,1]$. Each consumer is assumed to purchases one unit of product at most. D_i denotes the demand for each product. Following Li et al. (2019), consumer utility is computed as

$$U_i = \theta q_i - p_i. \tag{1}$$

A consumer who shows indifference between purchasing and non-purchasing product i is located in $\theta_i = \frac{p_i}{q_i}$, which is derived by setting Eq. (1) to 0.

Figure 2 presents the market structure. Markets 1 and 2 operate independently, and the decision of consumers in these markets to buy or not is segmented with utility value θ. Similarly, firms 1 and 2 operate independently and are located in different markets, where consumers can only purchase products from the corresponding firms. In Figure 2, the "cooperation" condition is denoted by the dashed line that separates firm 1 from firm 2. The markets of these two firms become indirectly connected when they choose to engage in a cooperative relationship. In this case, the consumers in market 1 can purchase products from the platform of firm 2, while the consumers in market 2 can purchase products from the platform of firm 1. Table 1 summarizes the relevant notations.

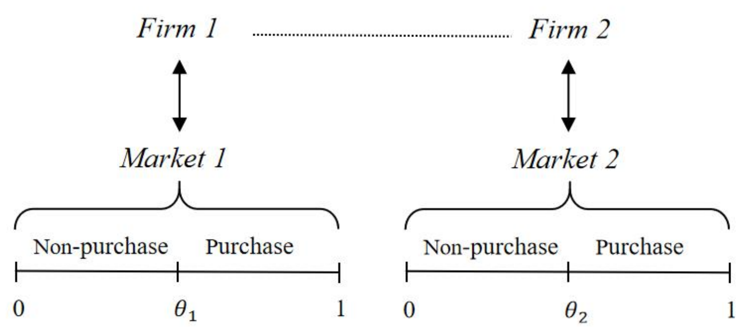

Figure 2. Market Segmentation

Table 1. Summary of Notations

p_i	Price of product i, $i \in \{1, 2\}$
D_i	Demand of product i, $i \in \{1, 2\}$
θ	Consumers' preference heterogeneity, $\theta \sim U(0,1)$
f	Listing fee, $f = (f_1 - f_2)$
q_i	Quality of product i, $i \in \{1, 2\}$, $0 < q_2 \leq q_1 \leq 1$
η	Market size discount factor, $0 < \eta < 1$

Note: Without loss of generality, we normalize $q_1 = 1$ *and* $0 < q_2 < 1$.

3.3.1 Benchmark: Case N (Non-cooperation)

Benchmark case *N* involves two independent platforms operating in different markets as shown in Figure 2. A consumer who shows indifference between purchasing and non-purchasing product *i* is located in $\theta = \frac{p_i}{q_i}$, whose value can be computed by setting Equation (1) to 0. The demand for product i can be expressed as $D_i = 1 - \frac{p_i}{q_i}$. Therefore, the profit for firm 1 is expressed as $\pi_1^N = p_1 D_1 = p_1\left(1 - \frac{p_1}{q_1}\right)$, and this firm seeks to solve the following profit-maximization problem:

$$\max_{p_1} \pi_1^N = p_1 D_1 = p_1\left(1 - \frac{p_1}{q_1}\right) \quad (2)$$

$$\text{Subject to } 0 \leq D_1 \leq 1 \quad (3)$$

$$p_1 \geq 0 \quad (4)$$

Inequality (3) guarantees that the demand is feasible and non-negative, while Inequality (4) guarantees a non-negative price. Solving the above problem yields an optimal price of $p_1^{N*} = \frac{q_1}{2}$ and maximum profit of $\pi_1^{N*} = \frac{q_1}{4}$. Without loss of generality, the proposed model is simplified by normalizing the qualities of products 1 and 2 as $q_1 = 1$ and q_2, $0 < q_2 \leq 1$, respectively. The optimal price and maximum profit for firm 1 are then $p_1^{N*} = \frac{1}{2}$ and $\pi_1^{N*} = \frac{1}{4}$, respectively.

Meanwhile, given that the two firms have asymmetric market sizes, the consumer base of firm 2 is assumed to be smaller than that of firm 1. In this profit function, consumer base discount factor η is added to the market size of firm 1, and $0 < \eta < 1$. The profit-maximization problem can be formulated as

$$\max_{p_2} \pi_2^N = p_2 \eta D_2 = p_2 \eta \left(1 - \frac{p_2}{q_2}\right) \quad (5)$$

$$\text{Subject to } 0 \leq D_2 \leq 1 \quad (6)$$

$$p_2 \geq 0 \quad (7)$$

The derivatives of function (5) with respect to p_2 are used to obtain the optimal price $p_2^{N*} = \frac{q_2}{2}$ and maximum profit $\pi_2^{N*} = \frac{q_2}{4}\eta$ from the first-order condition. Therefore, the total profit of firms 1 and 2 can be computed as the sum of their individual profits (*i.e.,* $\pi^{N*} = \pi_1^{N*} + \pi_2^{N*} = \frac{(1+\eta q_2)}{4}$).

3.3.2 Case *T* (*T*wo-way cooperation)

In the cooperation case, the two firms decide whether or not to adopt a two-way cooperation strategy. When adopting this strategy, both of these firms will sell each other's platforms to sell their products and will charge each other a fixed listing fee f_i for the use of their platforms. Given that firm 1 is larger and superior over firm 2 when bargaining the amount of listing fee, the latter is assumed to make the final payment $f = (f_1 - f_2)$ to the former. To illustrate, take the largest book seller in the world as an example. In 2022, firms pay *Amazon* a fixed listing fee of 99 cents per unit of goods sold through its platform but only pay 20 cents per unit of goods to the smaller *Etsy* for the same service (Brophy, 2022). In the two-way cooperation case, both *Amazon* and *Etsy* post links to each other's products on their respective platforms, thus allowing consumers, regardless of market, to purchase products from either company. Nevertheless, each of these firms make the decisions on how much their products will cost. When the product of one company is consigned to the platform of the other company, this product can be purchased by consumers from two different markets simultaneously. In this sense, a product compete takes place between these markets. However, a company that has limited consumer demand may refuse to participate in a cooperative relationship. Assuming that the quality of product 2 is inferior to that of product 1, the following inequality ensures the demand for both products and the partnership between the firms:

$$\theta_2 = \frac{p_2}{q_2} \leq p_1 = \theta_1.$$

Consumers will refuse to purchase product 2 when the above inequality does not hold, thereby resulting in profit losses for firm 2, which would subsequently reduce its consumer demand and force this firm to refuse a potential partnership offer from firm 1.

The utility functions $U = \theta q_1 - p_1$ and $U = \theta q_2 - p_2$ are derived for those consumers purchasing products 1 and 2, respectively, whereas the utility of those consumers who do not purchase any product is equal to 0. Following these utility functions, the market is split into three segments in equilibrium as shown in Figure 3.

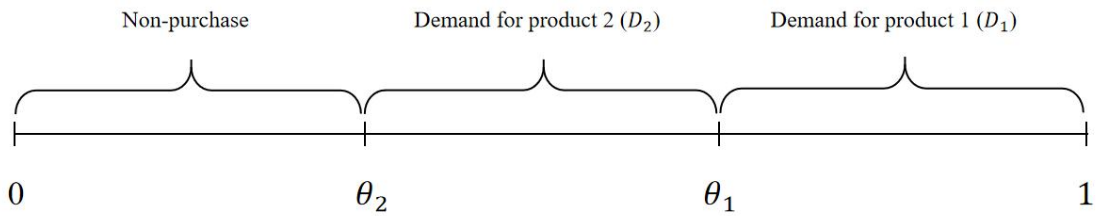

Figure 3. Market Structure under Co-Opetition

For critical points θ_1 and θ_2, the former represents a consumer showing indifference between purchasing products 1 and 2, whereas the latter represents a consumer showing indifference between purchasing product 2 and purchasing neither product. These critical points can be formulated as $\theta_1 = \frac{p_1 - p_2}{1 - q_2}$ and $\theta_2 = \frac{p_2}{q_2}$, and the demand for products 1 and 2 across different markets can be formulated as $D_1 = 1 - \theta_1 = 1 - \frac{p_1 - p_2}{1 - q_2}$ and $D_2 = \theta_1 - \theta_2 = \frac{p_1 - p_2}{1 - q_2} - \frac{p_2}{q_2}$, respectively. The profit-maximization problem of firm 1 in the cooperation context can be expressed as

$$\max_{p_1} \pi_1^T = p_1(1+\eta)\left(1 - \frac{p_1 - p_2}{1 - q_2}\right) + f \quad (8)$$

$$\text{Subject to } \ p_1 q_2 \geq p_2 \quad (9)$$

Product 1 can be simultaneously sold at markets 1 and 2 when firms engage in two-way cooperation. In other words, through two-way cooperation, firm 1 can expand its market size to $(1+\eta)$ by summing its own market and that of firm 2. In this context, the profit of firm 1 includes the listing fee f paid by firm 2. The profit function of this firm is then expressed as its revenue from product sales $p_1(1+\eta)\left(1 - \frac{p_1 - p_2}{1 - q_2}\right)$ plus the listing fee f paid by firm 2. By taking the derivatives of Eq. (8) with respect to p_1, $p_1 = \frac{1 - q_2 + p_2}{2}$ can be obtained from the first-order condition.

Meanwhile, the profit of firm 2 when engaged in two-way cooperation can be expressed as

$$\max_{p_2} \pi_2^T = p_2(1+\eta)\left(\frac{p_1 - p_2}{1 - q_2} - \frac{p_2}{q_2}\right) - f \quad (10)$$

$$\text{Subject to } \ p_1 q_2 \geq p_2. \quad (11)$$

Similar to firm 1, firm 2 expands its market size to $(1+\eta)$ through two-way cooperation in exchange for a listing fee. Therefore, the profit function of this firm can be computed by subtracting the listing fee from its sales revenue (i.e., $p_2(1+\eta)\left(\frac{p_1-p_2}{1-q_2}-\frac{p_2}{q_2}\right)-f$). By taking the derivatives of Eq. (10) with respect to p_2, $p_2=\frac{p_1 q_2}{2}$ can be derived from the first-order condition. Firms 1 and 2 obtain optimal prices of $p_1^{T*}=\frac{2(1-q_2)}{4-q_2}$ and $p_2^{T*}=\frac{q_2(1-q_2)}{4-q_2}$ after solving for $p_1=\frac{1-q_2+p_2}{2}$ and $p_2=\frac{p_1 q_2}{2}$, respectively. However, these optimal profits change to $\pi_1^{T*}=\frac{4(1+\eta)(1-q_2)}{(4-q_2)^2}+f$ and $\pi_2^{T*}=\frac{(1+\eta)q_2(1-q_2)}{(4-q_2)^2}-f$ after plugging $p_1^{T*}=\frac{2(1-q_2)}{4-q_2}$ and $p_2^{T*}=\frac{q_2(1-q_2)}{4-q_2}$ back into Eqs. (8) and (10), respectively. In this case, the total profit can be expressed as $\pi^{T*}=\pi_1^{T*}+\pi_2^{T*}=\frac{(1+\eta)(4+q_2)(1-q_2)}{(4-q_2)^2}$ in the case of two-way cooperation.

3.4 Co-Opetition Strategy of the Two Firms

The cooperation and benchmark cases are then compared to determine the best strategy and timing for the firms. First, the difference between the optimal profits of firm 1 in the two cases is computed as follows:

$$\Delta\pi_1=\pi_1^{T*}-\pi_1^{N*}=\frac{(16\eta-8(1+2\eta)q_2-q_2^2)}{4(4-q_2)^2}. \tag{12}$$

The comparisons are summarized in the following proposition.

Proposition 1: *(Firm 1, Profit Comparison).* The large firm has a unique threshold q_2^1 such that

(1) Firm 1 agrees to cooperate with firm 2 if product 2 has a quality that is below the cooperation threshold ($q_2<q_2^1$); otherwise, firm 1 refuses to cooperate with firm 2.

(2) Increasing the consumer base of firm 2 (η) also increases the threshold value (q_2^1).

Proof. See the Appendix.

The above proposition defines the ideal time for firm 1 to cooperate with firm 2. First, a leading player in the market prefers cooperating with firms that offer products with both high quality and vertical differentiation. To do otherwise would only intensify the competition in the market given that product demand can be influenced by a high product similarity. Under such intensified competition, the firm has no choice but to take a loss and reduce the prices of its products. Second, the product quality of the smaller firm can be reflected in the cooperation threshold. As firm 1 has a higher product quality than firm 2, the cooperation quality of the latter is denoted by the threshold q_2^1. Increasing this threshold shows that the product quality of firm 2 may be improved by engaging in a partnership with firm 1. However, this cooperation can increase the similarity in the products of firms 1 and 2 and consequently affect the profits of the former. Third, the larger firm becomes less willing to cooperate with the smaller firm when the product quality of the latter improves. However, an expansion in the consumer base of the smaller firm also increases the cooperation threshold of the larger firm. Especially for those firms with large consumer bases, an improvement in the product quality of small firms increases their tendency to enter partnerships with large firms. In sum, having a larger consumer base can positively influence cooperation and dampen the negative influence of product similarity (e.g., price wars between large and small firms).

The optimal profits of firm 2 are then compared as follows:

$$\Delta\pi_2 = \pi_2^{T*} - \pi_2^{N*} = \frac{q_2(4(1-3\eta)-4(1-\eta)q_2-\eta q_2{}^2)}{4(4-q_2)^2}.$$

Given the significant influence of market size on the sales of the corresponding monopoly (Campbell and Hopenhayn, 2005), the given case is explored in separate scenarios, namely, a scenario with a wide consumer base $\left(\frac{1}{2} < \eta < 1\right)$ and a scenario with a small consumer base $\left(0 < \eta < \frac{1}{2}\right)$. The results for the first scenario are summarized in Proposition 2.

Proposition 2: *(Firm 2, Large Consumer Base, Profit Comparison).* Firm 2 refuses to cooperate with firm 1 when the former has a large consumer base $\left(\frac{1}{2} < \eta < 1\right)$.

Proof. See the Appendix.

The above proposition suggests that if firm 2 has a consumer base that is more than half larger than that of firm 1, then the former refuses to cooperate with the latter. In this case, firms 1 and 2 are at cross purposes for several reasons. First, a small firm with a wide audience would naturally refuse the opportunity to work together with a large firm given that the negative effect of price competition cannot be offset by the benefits offered by such a wide consumer base. Second, choosing to cooperate with the large firm may place the small firm at risk of losing some of its consumers due to competition. Given these considerations, firm 2 is better off by launching its own platform and make good profit from its large consumer base without the help of firm 1. Proposition 3 summarizes the profit comparison results for firm 2 with a small consumer base $\left(0 < \eta < \frac{1}{2}\right)$.

Proposition 3: *(Firm 2, Smaller Consumer Base, Profit Comparison).* A small firm with a small consumer base $\left(0 < \eta < \frac{1}{2}\right)$ has a unique threshold q_2^2 such that

(1) If the quality of product 2 is below the threshold $\left(q_2 < q_2^2\right)$ and when the consumer base (η) of firm 1 $\left(0 < \eta < \frac{1}{3}\right)$ outsizes that of firm 2 by one third, then firm 2 would prefer to cooperate with firm 1.

(2) If the quality of product 2 is above the threshold $\left(q_2 > q_2^2\right)$ and when the consumer base (η) of firm 2 outsizes that of firm 1 $\left(\frac{1}{3} < \eta < \frac{1}{2}\right)$ by one third, then this firm refuses to cooperate with firm 1.

(3) The consumer base of firm 2 decreases in size when the threshold q_2^2 increases.

Proof. See the Appendix.

The above proposition suggests that the willingness of firm 2 to cooperate with firm 1 depends on the threshold q_2^2 when its consumer base is small, and such threshold reflects the product quality of the firm. Specifically, a low product quality and small consumer base would increase the willingness of firm 2 to cooperate with firm 1 in order to secure more profit-making opportunities and to increase its competitiveness in the market. By contrast, a small consumer base yet a relatively high product quality would reduce the willingness of firm 2 to cooperate with firm 1 given that the former has higher competitiveness than the latter.

By taking the above propositions into consideration, $q_2 < \min\left\{q_2^1 \cdot q_2^2\right\}$ is derived as the condition in which both firms 1 and 2 willingly cooperate with each other. The findings are summarized in the following proposition.

Proposition 4. *(Two-Way Cooperation, Threshold)*.

(1) When the product quality of firm 2 is below the threshold (q_2^1) and when its consumer base is relatively small ($0 < \eta < 0.25$), both firms 1 and 2 agree to cooperate at the threshold.

(2) When the product quality of firm 2 is below the threshold (q_2^2) and when its consumer base is relatively large, both firms 1 and 2 agree to cooperate at the threshold.

Proof. See the Appendix.

The conclusions stated in Propositions 2 and 3 have been confirmed in Proposition 4. Specifically, having a low product quality encourages firm 2 to engage in a two-way cooperation with firm 1. In addition, when the product quality of both firms 1 and 2 is highly vertically differentiated, they can gain profit from their cooperation. Otherwise, these firms are placed in a price competition, thus preventing them from reaping any benefit from their cooperation. In this case, a win–win cooperation between small and large firms can only be realized when they are selling differentiated products.

The total profits of these two firms are then compared between the benchmark and two-way cooperation cases. The difference in their profits can be expressed as

$$\Delta\pi = \pi^{T*} - \pi^{N*} = \frac{(16\eta - 4(1+7\eta)q_2 + (-5+4\eta)q_2{}^2 - \eta q_2{}^3)}{4(4-q_2)^2}. \quad (13)$$

By letting $h(q_2) = 16\eta - 4(1+7\eta)q_2 + (-5+4\eta)q_2{}^2 - \eta q_2{}^3$, the following lemma can be derived:

Lemma 1. The function $h(q_2)$ strictly decreases over interval $q_2 \in (0,1]$. There also exists a unique root $\tilde{q}_2$ such that $h(\tilde{q}_2) = 0$.

Proof. See the Appendix.

As shown in the above lemma, $h(\tilde{q}_2)$ strictly decreases, and $\tilde{q}_2$ is the only root. Given that $4(4 - q_2)^2 > 0$, the comparison $\Delta\pi$ can be further derived as follows.

Proposition 5. *(Two-way Cooperation, Total Profit Comparison).* When product 2 has low quality ($0 < q_2 < \tilde{q}_2$), both firms 1 and 2 will reap greater profit from the two-way cooperation, thus encouraging them to engage in such relationship. By contrast, when product 2 has high quality ($\tilde{q}_2 < q_2 < 1$), both firms will refuse to cooperate given that they would only receive low profit from the two-way cooperation.

Proof. See the Appendix.

Two-way cooperation does not yield any benefits for both firms when product 2 has a quality that exceeds the threshold $\tilde{q}_2$. In the opposite case, both firms are encouraged to cooperate as they can gain higher profits from two-way cooperation than from non-cooperation. In other words, these firms can gain more profit from two-way cooperation than from non-cooperation case when the quality of their products is highly vertically differentiated. Figure 4 shows that increasing the quality of product 2 reduces the profit margin of two-way cooperation. The total profits of both firms 1 and 2 in the two-way cooperation case will be lower than those in the non-cooperation case when the quality of product 2 exceeds $\tilde{q}_2$.

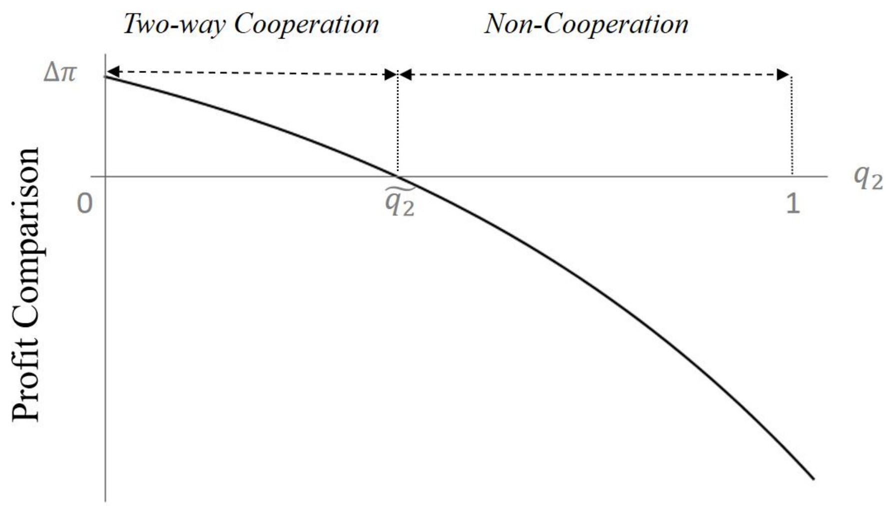

Figure 4. Total Profit Comparison.

3.5 Extension: Case O (One-way Cooperation)

As an extension, this study investigates the situation of firms 1 and 2 in a one-way cooperation situation. In this strategy, the products of small firms are linked by the large firm on its platform, and this action is not reciprocated by the small firms. Without loss of generality, firm 2 is assumed to pay firm 1 the listing fee f_2 to have its products listed on the latter's platform. However, firm 1 can only sell its products on its own platform.

The profit function of firm 1 in this case can be expressed as $\pi_1^O = p_1\left(1 - \frac{p_1 - p_2}{1 - q_2}\right) + f_2$, in which the first term denotes the profit earned by the firm from selling products on its own platform, whereas the second term denotes the listing fee received by firm 1 from firm 2. The superscript *O* stands for "Case <u>*O*</u> (<u>*O*</u>ne-way Cooperation)," The following profit-maximization problem is solved by firm 1:

$$\max_{p_1} \pi_1^O = p_1\left(1 - \frac{p_1 - p_2}{1 - q_2}\right) + f_2 \quad (14)$$

Subject to $p_1 q_2 \geq p_2$

By taking the derivatives of Eq. (14) with respect to p_1, $p_1 = \frac{1-q_2+p_2}{2}$ can be derived from the first-order condition. Meanwhile, the profit of firm 2 in the one-way cooperation case can be expressed as

$$\max_{p_2} \pi_2^O = p_2\left(\frac{p_1-p_2}{1-q_2} - \frac{p_2}{q_2}\right) + p_2\eta\left(1-\frac{p_2}{q_2}\right) - f_2 \quad (15)$$

Subject to $p_1 q_2 \geq p_2$

In Eq. (15), the first term represents the profit generated by firm 2 from its own platform, the second term denotes the profit earned by the firm from listing its products on the platform of firm 1, and the last term denotes the listing fee. By taking the derivatives of Eq. (15) with respect to p_2, $p_2 = \frac{(p_1+\eta(1-q_2))q_2}{2(q_2+(1+\eta)(1-q_2))}$ can be derived from the first-order condition.

Solving $p_1 = \frac{1-q_2+p_2}{2}$ and $p_2 = \frac{(p_1+\eta(1-q_2))q_2}{2(q_2+(1+\eta)(1-q_2))}$ yields $p_1^{O*} = \frac{(1-q_2)(2+\eta+\eta(1-q_2))}{3q_2+4(1+\eta)(1-q_2)}$ and $p_2^{O*} = \frac{q_2(1-q_2)(1+2\eta)}{3q_2+4(1+\eta)(1-q_2)}$ as the optimal prices for firms 1 and 2, respectively. These optimal profits change to $\pi_1^{O*} = \frac{(1-q_2)(2(1+\eta)-\eta q_2)^2}{(3q_2+4(1+\eta)(1-q_2))^2} + f_2$ and $\pi_2^{O*} = \frac{(1+2\eta)^2(1-q_2)q_2(1+\eta(1-q_2))}{\left(3q_2+4(1+\eta)(1-q_2)\right)^2} - f_2$ after plugging $p_1^{O*} = \frac{(1-q_2)(2+\eta+\eta(1-q_2))}{3q_2+4(1+\eta)(1-q_2)}$ and $p_2^{O*} = \frac{q_2(1-q_2)(1+2\eta)}{3q_2+4(1+\eta)(1-q_2)}$ back into Eqs. (14) and (15), respectively. In sum, the total profit is $\pi^{O*} = \pi_1^{O*} + \pi_2^{O*} = \frac{(1-q_2)(4(1+\eta)^2+(1+\eta)(1+4\eta^2)q_2-\eta(1+\eta(3+4\eta))q_2^2)}{\left(3q_2+4(1+\eta)(1-q_2)\right)^2}$ in the one-way cooperation case.

3.5.1 Analysis of one-way cooperation

One-way cooperation influences not only the entire market pattern but also the individual profits of firms 1 and 2. These firms participate in such setup as they believe that their participation is more beneficial than their non-participation. The profits of these firms are then compared between the one-way cooperation and benchmark cases. Results show that this type of cooperation is only feasible when it yields more profit for both firms compared with non-cooperation. The comparison is summarized as follows:

Proposition 6. When firms engage in one-way cooperation, the products of firm 2 are listed on the platform of firm 1, whereas firm 1 can only sell its products on its own platform.

(1) *(One-Way Cooperation, Firm 1).* Upon receiving payment of listing fee f_2 from firm 2, firm 1 agrees to engage in a one-way cooperation with this company.

(2) *(One-Way Cooperation, Firm 2).* When the listing fee f_2 is unaffordable, firm 2 refuses to engage in a one-way cooperation with firm 1.

(3) *(One-Way Cooperation).* A one-way cooperation does not take place as the one-way listing fee f_2 is unaffordable for firm 2.

Proof. See the Appendix.

In the one-way cooperation case, firm 2 chooses to sell its products on the platform of firm 1 given the huge market of the latter. In this way, these two firms share the same market owned by firm 1, but the market of firm 2 is not made available to firm 1. In exchange for a high listing fee, firm 1 allows firm 2 to catch up in their customer base competition by entering a one-way cooperation. By contrast, although firm 2 realizes that its consumer base can expand by entering a one-way cooperation with firm 1, its gains from such cooperation are far below the amount of listing fee paid. This situation greatly contrasts that in a two-way cooperation, where both firms agree to pay each other a listing fee. Therefore, the cooperation cost of firm 2 increases along with the listing fee.

Propositions 6(1) and 6(2) combined suggest that a one-way cooperation is impossible to realize without the participation of firm 2. Specifically, as summarized in Proposition 6(3), firm 2 refuses to engage in a one-way cooperation with firm 1 as the listing fee is far too high to be compensated by the possible benefits from having an expanded consumer base.

3.6 Conclusion

By exploring the optimal pricing strategies of one large and one small firm with two-sided platforms, this study reveals that these firms enter a co-opetition in e-commerce platforms. Specifically, these e-sellers, which offer vertically differentiated products and services, simultaneously compete and cooperate with each other by using each other's platforms to list their products. This study aims to determine the point at which these two firms enter a co-opetition and to find out whether such model can increase the profits of these firms in an oligopoly market. This study also checks for other forms of cooperation that can increase the profits of these firms.

To examine these problems, this study develops a co-opetition model involving a competition between one large and one small firm selling vertically differentiated products. Each of these firms has an online platform and a market. These firms are examined across the one-way (i.e., the large firm links the products of the small firm on its platform), two-way (i.e., both firms link each other's products on their respective platforms), and non-cooperation (i.e., these firms operate independently in their respective markets) scenarios. The profits of each firm across these scenarios are then compared.

Results show that both firms can earn more profit in the two-way cooperation scenario than in the non-cooperation scenario if the vertical differentiation of their product quality is sufficiently high. Specifically, two-way cooperation allows the consumers of one firm to purchase the goods of another firm without switching platforms, hence expanding the consumer base and increasing the profits of both firms. Meanwhile, setting a high listing fee will prevent the small firm from listing its products on the platform of the large firm, thereby preventing a one-way cooperation between these firms. The decision of these firms to enter a co-opetition depends on their product quality differentiation. Specifically, a higher product quality differentiation corresponds to a higher profit margin for both firms, whereas a low product quality differentiation can introduce a fierce price competition that can negatively affect the profits of these firms. Similarly, a low product quality differentiation dissuades consumers from purchasing products from another market, thereby reducing the benefits gained by either firm from the expansion of their consumer base.

This study contributes to two streams of literature that focus on vertically differentiated markets and co-opetition in platforms. On the one hand, this study enriches the literature on vertically differentiated markets by exploring the co-opetition strategies adopted by firms in two-sided platforms. Specifically, this study compares three competing strategies and formulates an optimal strategy for two e-commerce firms that compete with each other by selling vertically differentiated products. The results highlight how the differentiation in product quality can benefit those firms engaged in a co-opetition. On the other hand, this study enriches the co-opetition literature by being the first to study the co-opetition of firms with vertically differentiated products in the e-commerce context.

Some managerial insights can be derived from these results. First, these results offer insights on cooperation and competition that can may be helpful for e-sellers. The competitive advantages of these e-sellers become increasingly obvious along with the intensifying competition in the e-commerce market. Given that small e-sellers are outperformed by their large counterparts in terms of advertising investments, market shares, and product quality, they need to cooperate with these large e-sellers to expand their market share. Large e-sellers also gain more benefits from such relationship than from operating independently. Second, by engaging in co-opetition, these small and large e-sellers can give full play to their respective advantages to produce differentiated products and services and seize new markets at diverse levels. Third, the efficiency of these e-sellers also benefits from co-opetition by promoting a market competition. By subdividing vertically differentiated products, these e-sellers can generate network effects, enhance their resource allocation efficiency, and offer more benefits to their consumers.

Some limitations of this work may be addressed in future research. First, the proposed model merely focuses on e-commerce firms having their own online platforms. Given that co-opetition may manifest itself in various business activities, different industry characteristics may be incorporated into future co-opetition research. Second, the proposed competition model merely focuses on vertically differentiated markets, and no previous study has explored horizontally differentiated markets. The competition among firms in horizontally differentiated markets does not center on product quality given that the product choices of consumers is considered a “personal preference problem.” Therefore, future research should consider characterizing and comparing the models in horizontally differentiated markets with those in vertically differentiated markets. Third, customers in this study are assumed to belong to different markets. Future studies may consider investigating the situation in which all customers belong to one unified market with firms operating in the same market.

Appendix 1

Appendix 1A: How CDS Works

We adopt an example of a company borrowing money from a bank. A typical lending relationship consists of two parties—the lender and the borrower. However, when the lender (the bank) would like to protect itself against the borrower (the company)'s default, it may purchase a CDS with respect to the borrower's loan as an insurance against the risk of default. A new pair of relationship therefore occurs — a CDS seller and a CDS buyer. The CDS seller (the insurance company) offers a privately negotiated bilateral contract to the CDS buyer (the bank), through which the buyer pays a fee or premium to the seller to protect itself from possible losses. The compensation triggering event is often referred to as a "credit event", indicating that the borrower is unable to repay its debts or interests. Once a credit event occurs, the CDS seller will compensate the CDS buyer for the loss. Typically, a CDS contract has a maturity of 1 to 10 years, and most liquidity is concentrated in five years (Terzi and Uluçay, 2011).

Appendix 1B: Variables, Correlations, and Other Statistics

Table 1. Variable Definitions

Variable	Definitions
$TOTAL_{i,t}$	Sum of hardware and software investment
$HARDWARE_{i,t}$	Market value of IT hardware stock, by multiplying the number of personal computers (PCs) and servers at each company by the average prices of a PC and a server respectively
$SOFTWARE_{i,t}$	IT labor expense, by multiplying the Number of IT staff members of each firm by mean annual wage for all computer and mathematical science workers
$CDS_{i,t}$	A dummy that equals 1 if the option observation is associated with CDS, and 0 otherwise.
$SIZE_{i,t}$	Log of firm's total assets
$ROA_{i,t}$	Firm's return on assets
$LEVERAGE_{i,t}$	Firm's total liability divided by total assets
$UNCERTAINTY_{i,t}$	Standard deviation of firms' earnings in past 5 years
$DIVERSIFICATION_{i,t}$	Log of one plus number of business segments
$GROWTH_{i,t}$	Sales growth
$INDUSTRY\ CONCENTRATION_{i,t}$	The four-firm concentration ratio, which is the fraction of an industry's (at the 3-digit SIC level) total sales accounted for by its four largest firms
$CREDIT\ DUMMY_{i,t}$	A dummy variable that equals 1 if a firm has a Standard & Poor's debt rating; otherwise, 0
$MARKET\text{-}TO\text{-}BOOK_{i,t}$	Firm's market value divided by its book value
CASH	Firm's cash divided by total assets
$INSTITUTIONAL\ OWNERSHIP\ RATIO_{i,t}$	Total institutional ownership ratio
$INVESTMENT\ GRADE_{i,t}$	A dummy assigned to each investment grade level

Table 2. Correlation Table

		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
TOTAL$_{i,t}$	(1)	1							
HARDWARE$_{i,t}$	(2)	0.954***	1						
SOFTWARE$_{i,t}$	(3)	1.000***	0.950***	1					
CDS$_{i,t}$	(4)	-0.020**	0.032***	-0.019**	1				
SIZE$_{i,t}$	(5)	0.070***	0.103***	0.069***	0.579***	1			
ROA$_{i,t}$	(6)	0.054***	0.069***	0.053***	0.098***	0.304***	1		
LEVERAGE$_{i,t}$	(7)	0.036***	0.033***	0.036***	0.173***	0.164***	0.188***	1	
UNCERTAINTY$_{i,t}$	(8)	0.065***	0.081***	0.064***	0.123***	0.340***	0.478***	0.171***	1
DIVERSIFICATION$_{i,t}$	(9)	0.024***	0.031***	0.023***	0.152***	0.279***	0.051***	0.076***	0.122***
GROWTH$_{i,t}$	(10)	-0.0130	-0.018**	-0.0130	-0.018**	0.100***	0.212***	0.059***	0.071***
INDUSTRY CONCENTRATION$_{i,t}$	(11)	0.00300	0.00600	0.00200	0.021***	0.044***	0.133***	0.028***	0.097***
CREDIT DUMMY$_{i,t}$	(12)	0.034***	0.053***	0.034***	0.502***	0.699***	0.147***	0.307***	0.176***
MARKET-TO-BOOK$_{i,t}$	(13)	-0.020**	-0.0110	-0.020**	0.079***	0.095***	0.027***	0.387***	0.170***
CASH$_{i,t}$	(14)	0.0140	0.019**	0.0140	0.121***	0.191***	0.154***	0.346***	0.260***
INSTITUTIONAL OWNERSHIP RATIO$_{i,t}$	(15)	0.048***	0.065***	0.047***	0.212***	0.486***	0.287***	0.121***	0.237***

		(9)	(10)	(11)	(12)	(13)	(14)	(15)
DIVERSIFICATION$_{i,t}$	(9)	1						
GROWTH$_{i,t}$	(10)	0.00700	1					
INDUSTRY CONCENTRATION$_{i,t}$	(11)	0.013*	0.047***	1				
CREDIT DUMMY$_{i,t}$	(12)	0.224***	0.039***	-0.014*	1			
MARKET-TO-BOOK$_{i,t}$	(13)	0.00300	0.068***	0.041***	0.070***	1		
CASH$_{i,t}$	(14)	0.157***	0.00100	0.185***	0.238***	0.081***	1	
INSTITUTIONAL OWNERSHIP RATIO$_{i,t}$	(15)	0.127***	0.103***	0.030***	0.303***	0.036***	0.047***	1

Table 3. Summary Statistics Comparison before and after PSM

	Before PSM				After PSM			
	Mean		T-Test		Mean		T-Test	
Variable	Treated	Control	T	P>|T|	Treated	Control	T	P>|T|
$SIZE_{i,t}$	8.606	5.655	33.88	0.000	8.546	8.256	3.65	0.000
$ROA_{i,t}$	0.107	0.047	3.59	0.000	0.106	0.095	1.82	0.069
$LEVERAGE_{i,t}$	0.629	0.539	1.78	0.076	0.629	0.607	1.48	0.139
$UNCERTAINTY_{i,t}$	0.038	0.114	-0.28	0.005	0.039	0.043	-0.75	0.452
$DIVERSIFICATION_{i,t}$	1.362	1.121	9.40	0.000	1.357	1.359	-0.05	0.958
$GROWTH_{i,t}$	0.175	0.163	0.06	0.952	0.179	0.149	0.99	0.323
INDUSTRY CONCENTRATION$_{i,t}$	0.579	0.593	-1.32	0.187	0.577	0.561	1.01	0.313
CREDIT DUMMY$_{i,t}$	0.975	0.225	33.66	0.000	0.974	0.971	0.23	0.816
MARKET-TO-BOOK$_{i,t}$	0.439	-13.811	0.37	0.715	0.446	0.568	-3.81	0.000
$CASH_{i,t}$	0.595	0.144	-9.22	0.000	0.060	0.064	-0.52	0.601
INSTITUTIONAL OWNERSHIP RATIO$_{i,t}$	0.599	0.482	0.87	0.386	0.602	0.515	4.11	0.000

Table 4. Debt Dependence (Over five years)

	(1) *TOTAL*	(2) *TOTAL*	(3) *SOFTWARE*	(4) *SOFTWARE*	(5) *HARDWARE*	(6) *HARDWARE*
$CDS_{i,t}$	**-0.669*****	**-0.302**	**-0.687*****	**-0.339**	0.005	0.017
	(-3.325)	**(-0.552)**	**(-3.539)**	**(-0.659)**	(0.378)	(0.848)
$SIZE_{i,t}$	-2.464***	-2.743***	-2.175***	-2.575**	-0.210***	-0.445**
	(-6.766)	(-2.583)	(-6.944)	(-2.538)	(-7.471)	(-2.439)
$ROA_{i,t}$	-2.051	-16.406	-1.524	-15.135	-0.203	-0.394
	(-1.003)	(-0.880)	(-0.822)	(-0.866)	(-1.227)	(-1.075)
$LEVERAGE_{i,t}$	0.167	-8.343	-0.238	-7.663	0.154	-0.062
	(0.115)	(-0.816)	(-0.175)	(-0.800)	(1.384)	(-0.286)
$UNCERTAINTY_{i,t}$	2.850	37.050	2.424	34.924	0.149	1.469*
	(1.309)	(1.075)	(1.176)	(1.082)	(0.718)	(1.670)
$DIVERSIFICATION_{i,t}$	0.493	0.598	0.490	0.580	-0.004	0.036
	(1.605)	(0.903)	(1.639)	(0.923)	(-0.251)	(0.875)
$GROWTH_{i,t}$	0.434	-4.654	0.348	-4.413	0.022	-0.043
	(1.468)	(-1.044)	(1.314)	(-1.056)	(0.459)	(-1.116)
INDUSTRY $CONCENTRATION_{i,t}$	0.105	13.413	0.103	12.446	0.158	0.119
	(0.071)	(0.924)	(0.072)	(0.913)	(1.235)	(0.377)
CREDIT $DUMMY_{i,t}$	1.990***	0.944	1.823***	0.997	0.071	0.124
	(2.722)	(0.624)	(2.719)	(0.696)	(1.399)	(1.204)
MARKET-TO-$BOOK_{i,t}$	-0.020	-9.147	-0.012	-8.560	-0.007	-0.096
	(-0.115)	(-0.986)	(-0.072)	(-0.984)	(-0.793)	(-0.746)
$CASH_{i,t}$	-0.131	0.791	0.337	0.761	-0.250	-0.162*
	(-0.084)	(0.266)	(0.228)	(0.272)	(-1.616)	(-1.763)
INSTITUTIONAL OWNERSHIP $RATIO_{i,t}$	-0.541	-0.168	-0.736	-0.114	0.068	0.247
	(-0.883)	(-0.103)	(-1.293)	(-0.074)	(1.348)	(1.100)
INVESTMENT $GRADE_{i,t}$	Yes	Yes	Yes	Yes	Yes	Yes
Year Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Firm Fixed Effect	Yes	Yes	Yes	Yes	Yes	Yes
Constant	14.985***	17.711***	13.194***	16.182**	1.378***	2.872***
	(5.934)	(2.658)	(5.619)	(2.546)	(7.796)	(3.154)
N	6901	5500	6901	5500	8913	6971
R2	0.099	0.027	0.095	0.027	0.047	0.053

t statistics in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

Appendix 2

Proof for Propositions

Proposition 1.

Proof:

(1) We compare p_H^{RM} and p_H^{DM} by subtraction and let $p_H^{RM} - p_H^{DM}$.

$$p_H^{RM} - p_H^{DM} = 3 - c - \frac{\delta\theta}{2} + \frac{2(-9+c)}{8+\delta\theta} - \frac{\theta}{2} = 3 - c - \frac{1}{2}(1+\delta)\theta + \frac{2(-9+c)}{8+\delta\theta} = \frac{6-6c-\delta\theta-c\delta\theta-\frac{\delta^2\theta^2}{2}}{8+\delta\theta} = \frac{6-\frac{1}{2}\delta\theta(2+\delta\theta)-c(6+\delta\theta)}{8+\delta\theta}.$$

Because $8 + \delta\theta > 0$, $p_H^{RM} - p_H^{DM} > 0$ when $6 - \frac{1}{2}\delta\theta(2+\delta\theta) - c(6+\delta\theta) > 0$.

We get $p_H^{RM} - p_H^{DM} > 0$ when $0 < c < \frac{12-8\theta-2\delta\theta-\delta\theta^2-\delta^2\theta^2}{12+2\delta\theta}$

To improve readability, we let $c_1 = \frac{12-8\theta-2\delta\theta-\delta\theta^2-\delta^2\theta^2}{12+2\delta\theta}$.

So $p_H^{RM} > p_H^{DM}$ when $0 < c < c_1$.

(2) We compare p_L^{RM} and p_L^{DM} by subtraction and let $p_L^{RM} - p_L^{DM}$.

$$p_L^{RM} - p_L^{DM} = -\frac{\delta\theta(-10+2c+\delta\theta)}{2(8+\delta\theta)} - \frac{\delta\theta}{2} = -\frac{\delta\theta(-1+c+\delta\theta)}{8+\delta\theta}.$$

Because $8 + \delta\theta > 0$ and $-\delta\theta < 0$, $p_L^{RM} - p_L^{DM} > 0$ when $-1 + c + \delta\theta < 0$.

$p_L^{RM} > p_L^{DM}$ when $0 < c < 1 - \delta\theta$. To improve readability, we let $c_2 = 1 - \delta\theta$.

So $p_L^{RM} > p_L^{DM}$ when $0 < c < c_2$.

Proposition 2.

Proof:

(1) We compare D_H^{RM} and D_H^{DM} by subtraction and let $D_H^{RM} - D_H^{DM}$.

$$D_H^{RM} - D_H^{DM} = \frac{(2+\delta\theta)(-1+c+\delta\theta)}{(-1+\delta\theta)(8+\delta\theta)} - \frac{1}{2}\left(1 + \frac{2c}{(-1+\delta)\theta}\right) = -\frac{1}{2} + \frac{c}{\theta-\delta\theta} + \frac{(2+\delta\theta)(-1+c+\delta\theta)}{(-1+\delta\theta)(8+\delta\theta)}$$

$$= \frac{-\frac{8c}{-1+\delta}+\frac{8c\delta}{-1+\delta}-4\theta+4\delta\theta+\frac{7c\delta\theta}{-1+\delta}-\frac{7c\delta^2\theta}{-1+\delta}+\theta^2+\frac{3\delta\theta^2}{2}-\frac{5\delta^2\theta^2}{2}+\frac{c\delta^2\theta^2}{-1+\delta}-\frac{c\delta^3\theta^2}{-1+\delta}+\frac{\delta^2\theta^3}{2}-\frac{\delta^3\theta^3}{2}}{(\theta-\delta\theta)(-1+\delta\theta)(8+\delta\theta)}$$

$$= \frac{c\left(-\frac{8}{-1+\delta}+\frac{8\delta}{-1+\delta}+\frac{7\delta\theta}{-1+\delta}-\frac{7\delta^2\theta}{-1+\delta}+\frac{\delta^2\theta^2}{-1+\delta}-\frac{\delta^3\theta^2}{-1+\delta}\right)-4\theta+4\delta\theta+\theta^2+\frac{3\delta\theta^2}{2}-\frac{5\delta^2\theta^2}{2}+\frac{\delta^2\theta^3}{2}-\frac{\delta^3\theta^3}{2}}{(\theta-\delta\theta)(-1+\delta\theta)(8+\delta\theta)}.$$

Because $\theta - \delta\theta > 0, -1 + \delta\theta > 0, 8 + \delta\theta > 0$, $D_H^{RM} - D_H^{DM} < 0$ when $c\left(-\frac{8}{-1+\delta}+\frac{8\delta}{-1+\delta}+\frac{7\delta\theta}{-1+\delta}-\frac{7\delta^2\theta}{-1+\delta}+\frac{\delta^2\theta^2}{-1+\delta}-\frac{\delta^3\theta^2}{-1+\delta}\right)-4\theta+4\delta\theta+\theta^2+\frac{3\delta\theta^2}{2}-\frac{5\delta^2\theta^2}{2}+\frac{\delta^2\theta^3}{2}-\frac{\delta^3\theta^3}{2} < 0$.

we get $D_H^{RM} < D_H^{DM}$ when $0 < c < \frac{-4\theta+4\delta\theta+5\delta\theta^2-5\delta^2\theta^2-\delta^2\theta^3+\delta^3\theta^3}{-16+4\theta+10\delta\theta+2\delta\theta^2}$.

To improve readability, we let $c_3 = \frac{-4\theta+4\delta\theta+5\delta\theta^2-5\delta^2\theta^2-\delta^2\theta^3+\delta^3\theta^3}{-16+4\theta+10\delta\theta+2\delta\theta^2}$.

So $D_H^{RM} < D_H^{DM}$ when $0 < c < c_3$.

(2) We compare D_L^{RM} and D_L^{DM} by subtraction and let $D_L^{RM} - D_L^{DM}$.

$$D_L^{RM} - D_L^{DM} = \frac{1}{6}\left(3-\frac{2c}{-1+\delta\theta}+\frac{2(-9+c)}{8+\delta\theta}\right)-\frac{c}{\theta-\delta\theta} = \frac{c}{(-1+\delta)\theta}+\frac{1}{6}\left(3-\frac{2c}{-1+\delta\theta}+\frac{2(-9+c)}{8+\delta\theta}\right)$$

$$= \frac{1}{(\theta-\delta\theta)(-1+\delta\theta)(8+\delta\theta)}\left(-4\theta+4\delta\theta+\frac{7\delta\theta^2}{2}-\frac{7\delta^2\theta^2}{2}+\frac{\delta^2\theta^3}{2}-\frac{\delta^3\theta^3}{2}+\frac{8c\theta}{\theta-\delta\theta}-\frac{8c\delta\theta}{\theta-\delta\theta}-\frac{7c\delta\theta^2}{\theta-\delta\theta}+\frac{7c\delta^2\theta^2}{\theta-\delta\theta}-\frac{c\delta^2\theta^3}{\theta-\delta\theta}+\frac{c\delta^3\theta^3}{\theta-\delta\theta}+\frac{8c\theta}{3(-1+\delta\theta)}-\frac{8c\delta\theta}{3(-1+\delta\theta)}-\frac{7c\delta\theta^2}{3(-1+\delta\theta)}+\frac{7c\delta^2\theta^2}{3(-1+\delta\theta)}-\frac{c\delta^2\theta^3}{3(-1+\delta\theta)}+\frac{c\delta^3\theta^3}{3(-1+\delta\theta)}+\frac{24\theta}{8+\delta\theta}-\frac{8c\theta}{3(8+\delta\theta)}-\frac{24\delta\theta}{8+\delta\theta}+\frac{8c\delta\theta}{3(8+\delta\theta)}-\frac{21\delta\theta^2}{8+\delta\theta}+\frac{7c\delta\theta^2}{3(8+\delta\theta)}+\frac{21\delta^2\theta^2}{8+\delta\theta}-\frac{7c\delta^2\theta^2}{3(8+\delta\theta)}-\frac{3\delta^2\theta^3}{8+\delta\theta}+\frac{c\delta^2\theta^3}{3(8+\delta\theta)}+\frac{3\delta^3\theta^3}{8+\delta\theta}-\frac{c\delta^3\theta^3}{3(8+\delta\theta)}\right)$$

$$= \frac{8c-\frac{1}{2}(-1+\delta)\theta(-1+\delta\theta)(2+\delta\theta)-c\theta(3+\delta(4+\delta\theta))}{(\theta-\delta\theta)(-1+\delta\theta)(8+\delta\theta)}.$$

Because $\theta - \delta\theta > 0, -1 + \delta\theta > 0, 8 + \delta\theta > 0$, $D_L^{RM} > D_L^{DM}$ when $8c - \frac{1}{2}(-1+\delta)\theta(-1+\delta\theta)(2+\delta\theta) - c\theta\big(3+\delta(4+\delta\theta)\big) = c\big(8-\theta\big(3+\delta(4+\delta\theta)\big)\big) - \frac{1}{2}(-1+\delta)\theta(-1+\delta\theta)(2+\delta\theta) > 0$.

We get $D_L^{RM} > D_L^{DM}$ when $0 < c < \frac{-2\theta+2\delta\theta+\delta\theta^2-\delta^2\theta^2+\delta^2\theta^3-\delta^3\theta^3}{-16+6\theta+8\delta\theta+2\delta^2\theta^2}$.

To improve readability, we let $c_4 = \frac{-2\theta+2\delta\theta+\delta\theta^2-\delta^2\theta^2+\delta^2\theta^3-\delta^3\theta^3}{-16+6\theta+8\delta\theta+2\delta^2\theta^2}$.

So $D_L^{RM} > D_L^{DM}$ when $0 < c < c_4$.

Proposition 3.

Proof:

We compare π^{RM} and π^{DM} by subtraction and let $\pi^{RM} - \pi^{DM}$.

$$\pi^{RM} - \pi^{DM} = \frac{\delta\theta}{4} - \frac{(-1+c+\delta\theta)^2}{(-1+\delta\theta)(8+\delta\theta)} - \frac{1}{4}\left(-2(2c) - \frac{(2c)^2}{(-1+\delta)\theta} + \theta\right)$$

$= \frac{1}{4}\left(4c + \frac{4c^2}{(-1+\delta)\theta} - \theta + \delta\theta - \frac{4(-1+c+\delta\theta)^2}{(-1+\delta\theta)(8+\delta\theta)}\right)$

$= \frac{1}{\theta(-1+\delta\theta)(8+\delta\theta)}\Big(-\frac{8c^2}{-1+\delta} - 8c\theta + \frac{7c^2\delta\theta}{-1+\delta} + 2\theta^2 - 2\delta\theta^2 + 7c\delta\theta^2 + \frac{c^2\delta^2\theta^2}{-1+\delta} - \frac{7\delta\theta^3}{4} + \frac{7\delta^2\theta^3}{4} + c\delta^2\theta^3 - \frac{\delta^2\theta^4}{4} + \frac{\delta^3\theta^4}{4} + \frac{8\theta}{(-1+\delta\theta)(8+\delta\theta)} - \frac{16c\theta}{(-1+\delta\theta)(8+\delta\theta)} + \frac{8c^2\theta}{(-1+\delta\theta)(8+\delta\theta)} - \frac{23\delta\theta^2}{(-1+\delta\theta)(8+\delta\theta)} + \frac{30c\delta\theta^2}{(-1+\delta\theta)(8+\delta\theta)} - \frac{7c^2\delta\theta^2}{(-1+\delta\theta)(8+\delta\theta)} + \frac{21\delta^2\theta^3}{(-1+\delta\theta)(8+\delta\theta)} - \frac{12c\delta^2\theta^3}{(-1+\delta\theta)(8+\delta\theta)} - \frac{c^2\delta^2\theta^3}{(-1+\delta\theta)(8+\delta\theta)} - \frac{5\delta^3\theta^4}{(-1+\delta\theta)(8+\delta\theta)} - \frac{2c\delta^3\theta^4}{(-1+\delta\theta)(8+\delta\theta)} - \frac{\delta^4\theta^5}{(-1+\delta\theta)(8+\delta\theta)}\Big)$

$= \frac{c\theta(-1+\delta\theta)(6+\delta\theta) + \frac{c^2(-8+\theta+\delta\theta(6+\delta\theta))}{-1+\delta} + \frac{1}{4}\theta(-4+\theta(8+\delta\theta(-7+3\delta+(-1+\delta)\delta\theta)))}{\theta(-1+\delta\theta)(8+\delta\theta)}.$

Because $\theta > 0, -1+\delta\theta < 0, 8+\delta\theta > 0, \pi^{RM} - \pi^{DM} < 0$ when $c\theta(-1+\delta\theta)(6+\delta\theta) + \frac{c^2(-8+\theta+\delta\theta(6+\delta\theta))}{-1+\delta} + \frac{1}{4}\theta\left(-4+\theta\big(8+\delta\theta(-7+3\delta+(-1+\delta)\delta\theta)\big)\right) > 0$.

First, for the parameter of c^2, we would like to see if $\frac{(-8+\theta+\delta\theta(6+\delta\theta))}{-1+\delta}$ is positive or negative.

We let $h(c) = \frac{c^2(-8+\theta+\delta\theta(6+\delta\theta))}{-1+\delta} + c\theta(-1+\delta\theta)(6+\delta\theta) + \frac{1}{4}\theta\left(-4+\theta\left(8+\delta\theta(-7+3\delta+(-1+\delta)\delta\theta)\right)\right)$

For the parameter of c^2, we would like to see if $\frac{(-8+\theta+\delta\theta(6+\delta\theta))}{-1+\delta}$ is positive or negative.

We assume that $\frac{(-8+\theta+\delta\theta(6+\delta\theta))}{-1+\delta} < 0$.

We know that $-1+\delta < 0$. We let $g(\theta) = -8+\theta+\delta\theta(6+\delta\theta)$ and solve for $g(\theta) = -8+\theta+\delta\theta(6+\delta\theta) = -8+\theta+6\delta\theta+\delta^2\theta^2 > 0$.

We get two roots, $\theta^1 = \frac{-1-6\delta-\sqrt{1+12\delta+68\delta^2}}{2\delta^2} < 0$ and $\theta^2 = \frac{-1-6\delta+\sqrt{1+12\delta+68\delta^2}}{2\delta^2} > 0$

However, when we compare θ^2 with 1, we let $\theta^2 = \frac{-1-6\delta+\sqrt{1+12\delta+68\delta^2}}{2\delta^2} > 1$.

Simplifying $\sqrt{1+12\delta+68\delta^2} > 2\delta^2+6\delta+1$, we get $\delta^2+6\delta-7<0$.

So $\theta^2 = \frac{-1-6\delta+\sqrt{1+12\delta+68\delta^2}}{2\delta^2} > 1$ always holds. Because $0<\theta<1$, $g(\theta)>0$ does not hold.

The parameter of c^2, $\frac{(-8+\theta+\delta\theta(6+\delta\theta))}{-1+\delta} > 0$.

Second, we solve for $h(c) = 0$. We get two roots,

$c_5 = \frac{-6\theta+6\delta\theta+5\delta\theta^2-5\delta^2\theta^2+\delta^2\theta^3-\delta^3\theta^3}{2(-8+\theta+6\delta\theta+\delta^2\theta^2)} -$
$\frac{1}{2}\sqrt{\frac{32\theta-32\delta\theta-32\theta^2-28\delta\theta^2+60\delta^2\theta^2+8\theta^3+36\delta\theta^3-12\delta^2\theta^3-32\delta^3\theta^3-7\delta\theta^4-3\delta^2\theta^4+7\delta^3\theta^4+3\delta^4\theta^4-\delta^2\theta^5-\delta^3\theta^5+\delta^4\theta^5+\delta^5\theta^5}{(-8+\theta+6\delta\theta+\delta^2\theta^2)^2}}$

$= -\frac{(-1+\delta)(\theta(-1+\delta\theta)(6+\delta\theta)+\sqrt{\frac{\theta(-1+\delta\theta)(8+\delta\theta)(-2+\theta+\delta\theta)^2}{-1+\delta}})}{2(-8+\theta+\delta\theta(6+\delta\theta))}$ and

$c_6 = \frac{-6\theta+6\delta\theta+5\delta\theta^2-5\delta^2\theta^2+\delta^2\theta^3-\delta^3\theta^3}{2(-8+\theta+6\delta\theta+\delta^2\theta^2)} +$
$\frac{1}{2}\sqrt{\frac{32\theta-32\delta\theta-32\theta^2-28\delta\theta^2+60\delta^2\theta^2+8\theta^3+36\delta\theta^3-12\delta^2\theta^3-32\delta^3\theta^3-7\delta\theta^4-3\delta^2\theta^4+7\delta^3\theta^4+3\delta^4\theta^4-\delta^2\theta^5-\delta^3\theta^5+\delta^4\theta^5+\delta^5\theta^5}{(-8+\theta+6\delta\theta+\delta^2\theta^2)^2}} ==$
$\frac{(-1+\delta)(-\theta(-1+\delta\theta)(6+\delta\theta)+\sqrt{\frac{\theta(-1+\delta\theta)(8+\delta\theta)(-2+\theta+\delta\theta)^2}{-1+\delta}})}{2(-8+\theta+\delta\theta(6+\delta\theta))}$.

As we already know that $\frac{(-8+\theta+\delta\theta(6+\delta\theta))}{-1+\delta} > 0$, $h(c)$ is a quadratic function with opening upwards with respect to c.

Because $0 < c < 1$, c_5 should be greater than 0 and c_6 should be smaller than 1.

We get $h(0) = \frac{1}{4}\theta\left(-4 + \theta\left(8 + \delta\theta(-7 + 3\delta + (-1+\delta)\delta\theta)\right)\right)$.

We solve for $h(0) > 0$. $h(0) > 0$ holds when $-\frac{2(-2+\delta)}{(-1+\delta)\delta} + 2\sqrt{-\frac{-4+3\delta}{(-1+\delta)^2\delta^2}} < \theta < 1$.

We get $h(1) = \frac{1(-8+\theta+\delta\theta(6+\delta\theta))}{-1+\delta} + (6+\delta\theta)\theta(-1+\delta\theta) + \frac{1}{4}\theta\left(-4 + \theta\left(8 + \delta\theta(-7 + 3\delta + (-1+\delta)\delta\theta)\right)\right) = -\frac{8}{-1+\delta} - 7\theta + \frac{\theta}{-1+\delta} + \frac{6\delta\theta}{-1+\delta} + 2\theta^2 + 5\delta\theta^2 + \frac{\delta^2\theta^2}{-1+\delta} - \frac{7\delta\theta^3}{4} + \frac{7\delta^2\theta^3}{4} - \frac{\delta^2\theta^4}{4} + \frac{\delta^3\theta^4}{4}$.

As $0 < \theta < 1$ and $0 < \delta < 1$, $h(1) > 0$ always holds.

The discriminant of this quadratic equation $h(c) = 0$ is: $\left(\theta(-1+\delta\theta)(6+\delta\theta)\right)^2 -$
$\frac{\theta(-8+\theta+\delta\theta(6+\delta\theta))}{-1+\delta}\left(-4 + \theta\left(8 + \delta\theta(-7 + 3\delta + (-1+\delta)\delta\theta)\right)\right) = 36\theta - \frac{32\theta}{-1+\delta} + \frac{68\theta^2}{-1+\delta} - 60\delta\theta^2 + \frac{24\delta\theta^2}{-1+\delta} -$
$\frac{8\theta^3}{-1+\delta} - \frac{104\delta\theta^3}{-1+\delta} + 13\delta^2\theta^3 + \frac{28\delta^2\theta^3}{-1+\delta} + \frac{7\delta\theta^4}{-1+\delta} + \frac{23\delta^2\theta^4}{-1+\delta} + 10\delta^3\theta^4 - \frac{10\delta^3\theta^4}{-1+\delta} + \frac{\delta^2\theta^5}{-1+\delta} + \frac{12\delta^3\theta^5}{-1+\delta} + \delta^4\theta^5 - \frac{9\delta^4\theta^5}{-1+\delta} +$
$\frac{\delta^4\theta^6}{-1+\delta} - \frac{\delta^5\theta^6}{-1+\delta}$

$= \frac{1}{-1+\delta}(-68\theta + 36\delta\theta + 68\theta^2 + 84\delta\theta^2 - 60\delta^2\theta^2 - 8\theta^3 - 104\delta\theta^3 + 15\delta^2\theta^3 + 13\delta^3\theta^3 + 7\delta\theta^4 +$
$23\delta^2\theta^4 - 20\delta^3\theta^4 + 10\delta^4\theta^4 + \delta^2\theta^5 + 12\delta^3\theta^5 - 10\delta^4\theta^5 + \delta^5\theta^5 + \delta^4\theta^6 - \delta^5\theta^6) > 0$.

The discriminant is always positive when $0 < \theta < 1$ and $0 < \delta < 1$, ensuring that the equation has two real solutions.

So $0 < c_5$ and $c_6 < 1$.

To sum up, we get $\pi^{RM} < \pi^{DM}$ when $\frac{-6\theta+6\delta\theta+5\delta\theta^2-5\delta^2\theta^2+\delta^2\theta^3-\delta^3\theta^3}{2(-8+\theta+6\delta\theta+\delta^2\theta^2)} + \frac{1}{2}\sqrt{\frac{32\theta-32\delta\theta-32\theta^2-28\delta\theta^2+60\delta^2\theta^2+8\theta^3+36\delta\theta^3-12\delta^2\theta^3-32\delta^3\theta^3-7\delta\theta^4-3\delta^2\theta^4+7\delta^3\theta^4+3\delta^4\theta^4-\delta^2\theta^5-\delta^3\theta^5+\delta^4\theta^5+\delta^5\theta^5}{(-8+\theta+6\delta\theta+\delta^2\theta^2)^2}} < c < 1$.

In the second case, $\pi^{RM} < \pi^{DM}$ when $0 < c < \frac{-6\theta+6\delta\theta+5\delta\theta^2-5\delta^2\theta^2+\delta^2\theta^3-\delta^3\theta^3}{2(-8+\theta+6\delta\theta+\delta^2\theta^2)} - \frac{1}{2}\sqrt{\frac{32\theta-32\delta\theta-32\theta^2-28\delta\theta^2+60\delta^2\theta^2+8\theta^3+36\delta\theta^3-12\delta^2\theta^3-32\delta^3\theta^3-7\delta\theta^4-3\delta^2\theta^4+7\delta^3\theta^4+3\delta^4\theta^4-\delta^2\theta^5-\delta^3\theta^5+\delta^4\theta^5+\delta^5\theta^5}{(-8+\theta+6\delta\theta+\delta^2\theta^2)^2}}$ and

$-\frac{2(-2+\delta)}{(-1+\delta)\delta} + 2\sqrt{-\frac{-4+3\delta}{(-1+\delta)^2\delta^2}} < \theta < 1$.

To improve readability, we let

$\theta_1 = -\frac{2(-2+\delta)}{(-1+\delta)\delta} + 2\sqrt{-\frac{-4+3\delta}{(-1+\delta)^2\delta^2}}$, $c_5 = \frac{-6\theta+6\delta\theta+5\delta\theta^2-5\delta^2\theta^2+\delta^2\theta^3-\delta^3\theta^3}{2(-8+\theta+6\delta\theta+\delta^2\theta^2)} - \frac{1}{2}\sqrt{\frac{32\theta-32\delta\theta-32\theta^2-28\delta\theta^2+60\delta^2\theta^2+8\theta^3+36\delta\theta^3-12\delta^2\theta^3-32\delta^3\theta^3-7\delta\theta^4-3\delta^2\theta^4+7\delta^3\theta^4+3\delta^4\theta^4-\delta^2\theta^5-\delta^3\theta^5+\delta^4\theta^5+\delta^5\theta^5}{(-8+\theta+6\delta\theta+\delta^2\theta^2)^2}}$, and

$c_6 = \frac{-6\theta+6\delta\theta+5\delta\theta^2-5\delta^2\theta^2+\delta^2\theta^3-\delta^3\theta^3}{2(-8+\theta+6\delta\theta+\delta^2\theta^2)} + \frac{1}{2}\sqrt{\frac{32\theta-32\delta\theta-32\theta^2-28\delta\theta^2+60\delta^2\theta^2+8\theta^3+36\delta\theta^3-12\delta^2\theta^3-32\delta^3\theta^3-7\delta\theta^4-3\delta^2\theta^4+7\delta^3\theta^4+3\delta^4\theta^4-\delta^2\theta^5-\delta^3\theta^5+\delta^4\theta^5+\delta^5\theta^5}{(-8+\theta+6\delta\theta+\delta^2\theta^2)^2}}$.

So $\pi^{RM} < \pi^{DM}$ when $c_6 < c < 1$; and when $0 < c < c_5$ and $\theta_1 < \theta < 1$.

Table 4.

Proof:

The demands in the two channels are expressed as $D_L^{DM} = v_H^{DM} - v_L^{DM} = \frac{p_H^{DM}+c-p_L^{DM}}{\theta(1-\delta)} - \frac{p_L^{DM}}{\delta\theta}$ and

$D_H^{DM} = \frac{1+\gamma D_L^{DM} - \frac{p_H^{DM}+c-p_L^{DM}}{\theta(1-\delta)}}{1-\gamma} = \frac{\delta(c(-1+\gamma)+\theta-\delta\theta+(-1+\gamma)p_H^{DM})+(-\gamma+\delta)p_L^{DM}}{(-1+\gamma)(-1+\delta)\delta\theta}$. The profit function is still $\pi^{DM} = p_L^{DM}D_L^{DM} + p_H^{DM}D_H^{DM} = \frac{(-1+\gamma)\delta(p_H^{DM})^2+(-1+\gamma)p_L^{DM}(-c\delta+p_L^{DM})+p_H^{DM}(\delta(c(-1+\gamma)+\theta-\delta\theta)-(\gamma+(-2+\gamma)\delta)p_L^{DM})}{(-1+\gamma)(-1+\delta)\delta\theta}$.

To derive the optimal prices, we take derivatives of π^{DM} with respect to p_L^{DM}. The partial derivative function is $\frac{\partial(\pi^{DM})}{\partial(p_L^{DM})} = -\frac{(\gamma+(-2+\gamma)\delta)p_H^{DM}+(-1+\gamma)(c\delta-2p_L^{DM})}{(-1+\gamma)(-1+\delta)\delta\theta}$ (13). Similarly, we take derivatives of π^{DM} with respect to p_H^{DM}. The partial derivative function is $\frac{\partial(\pi^{DM})}{\partial(p_H^{DM})}=\frac{\delta(c(-1+\gamma)+\theta-\delta\theta+2(-1+\gamma)p_H^{DM})-(\gamma+(-2+\gamma)\delta)p_L^{DM}}{(-1+\gamma)(-1+\delta)\delta\theta}$ (14).

We let $(13)=(14)=0$. Based on the simultaneous equations, we get optimal $p_L^{DM}=\frac{\delta(c(-1+\gamma)\gamma+(\gamma+(-2+\gamma)\delta)\theta}{\gamma^2-(-2+\gamma)^2\delta}$ and $p_H^{DM}=\frac{(1-\gamma)\delta(c(-2+\gamma)+2\theta)}{-\gamma^2+(-2+\gamma)^2\delta}$.

We substitute p_L^{DM} and p_H^{DM} into $D_L^{DM}=v_H^{DM}-v_L^{DM}=\frac{p_H^{DM}+c-p_L^{DM}}{\theta(1-\delta)}-\frac{p_L^{DM}}{\delta\theta}$ and $D_H^{DM}=\frac{1+\gamma D_L^{DM}-\frac{p_H^{DM}+c-p_L^{DM}}{\theta(1-\delta)}}{1-\gamma}$. We get optimal $D_L^{DM}=\frac{c(\gamma+(-2+\gamma)\delta)+\gamma(-1+\delta)\theta}{(-1+\delta)(-\gamma^2+(-2+\gamma)^2\delta)\theta}$ and $D_H^{DM}=\frac{\delta(2c(-1+\gamma)+(-2+\gamma)(-1+\delta)\theta)}{(1-\delta)(-\gamma^2+(-2+\gamma)^2\delta)\theta}$.

Finally, we get optimal $\pi^{DM}=\frac{\delta(c^2(-1+\gamma)+c(-2+\gamma)(-1+\delta)\theta+(-1+\delta)\theta^2)}{(-1+\delta)(-\gamma^2+(-2+\gamma)^2\delta)\theta}$.

Table 5.

Proof:

To derive the optimal prices, we take derivatives of π^{RM} with respect to p_L^{RM}. The partial derivative function is $\frac{\partial(\pi^{RM})}{\partial(p_L^{RM})}=\frac{2w\gamma+w(-3+\gamma)\delta\theta+\delta\theta(-1+c(-1+\gamma)+\delta\theta)}{-4+3\gamma+\delta\theta}$ (15). Similarly, we take derivatives of π_r^{RM} with respect to p_H^{RM}. The partial derivative function is $\frac{\partial(\pi_r^{RM})}{\partial(p_H^{RM})}=\frac{w(\gamma^2+2(1+(-3+\gamma)\gamma)\delta\theta+\delta^2\theta^2)-(-1+\gamma)\delta\theta(2-2\delta\theta+c(-2+\gamma+\delta\theta))}{(-1+\gamma)\delta\theta(-4+3\gamma+\delta\theta)}$ (16). Then we take partial derivatives of π^{RM} with respect to w. $\frac{\partial(\pi^{RM})}{\partial(w)}=\frac{-\delta\theta(8+2c(-4+\gamma)(-1+\gamma)2+7(-2+\gamma)\gamma+2(-2+\gamma)\gamma\delta\theta+\delta 2\theta 2)+2w(\gamma 3-(-2+\gamma)(4+(-7+\gamma)\gamma)\delta\theta+\delta 2\theta 2)}{(-1+\gamma)\delta\theta(-4+3\gamma+\delta\theta)2}$ (17).

By letting (17)=0, we get optimal $w=-\frac{\delta\theta(8+2c(-4+\gamma)(-1+\gamma)^2+7(-2+\gamma)\gamma+2(-2+\gamma)\gamma\delta\theta+\delta^2\theta^2)}{-2\gamma^3+2(-2+\gamma)(4+(-7+\gamma)\gamma)\delta\theta-2\delta^2\theta^2}$.

We substitute $w=-\frac{\delta\theta(8+2c(-4+\gamma)(-1+\gamma)^2+7(-2+\gamma)\gamma+2(-2+\gamma)\gamma\delta\theta+\delta^2\theta^2)}{-2\gamma^3+2(-2+\gamma)(4+(-7+\gamma)\gamma)\delta\theta-2\delta^2\theta^2}$ into (15) and (16), and let $(15)=(16)=0$. Based on the simultaneous equations, we get optimal $p_L^{RM}=-\frac{(-1+\gamma)\delta\theta(2c\gamma^2+\delta\theta(-10+2c+\delta\theta)+\gamma(4-4c+5\delta\theta))}{-2\gamma^3+2(-2+\gamma)(4+(-7+\gamma)\gamma)\delta\theta-2\delta^2\theta^2}$ and $p_H^{RM}=-\frac{2-2\delta\theta+c(-2+\gamma+\delta\theta)+\frac{(8+2c(-4+\gamma)(-1+\gamma)^2+7(-2+\gamma)\gamma+2(-2+\gamma)\gamma\delta\theta+\delta^2\theta^2)(\gamma^2+2(1+(-3+\gamma)\gamma)\delta\theta+\delta^2\theta^2)}{(-1+\gamma)(-2\gamma^3+2(-2+\gamma)(4+(-7+\gamma)\gamma)\delta\theta-2\delta^2\theta^2)}}{-4+3\gamma+\delta\theta}$.

We substitute p_L^{RM} and p_H^{RM} into D_L^{RM} and D_H^{RM}. We get optimal $D_L^{RM} = \frac{1}{6}(-\frac{3}{-1+\gamma} - \frac{2c}{-1+\delta\theta} - \frac{6(-2+\gamma)\gamma+2c\gamma(6+(-6+\gamma)\gamma)-2c\delta\theta+3(-3+\gamma)(-2+\gamma)\delta\theta}{\gamma^3-(-2+\gamma)(4+(-7+\gamma)\gamma)\delta\theta+\delta^2\theta^2})$ and $D_H^{DM} = \frac{(\gamma^2+2(1+(-3+\gamma)\gamma)\delta\theta+\delta^2\theta^2)(2c(-1+\gamma)+(-2+\gamma)(-1+\delta\theta))}{2(-1+\gamma)(-1+\delta\theta)(\gamma^3-(-2+\gamma)(4+(-7+\gamma)\gamma)\delta\theta+\delta^2\theta^2)}$.

Finally, we get optimal $\pi^{RM} = -\frac{\delta\theta(4c^2(-1+\gamma)^3+4c(-2+\gamma)(-1+\gamma)^2(-1+\delta\theta)+(-1+\delta\theta)((2+\delta\theta)^2+\gamma^2(5+4\delta\theta)-2\gamma(4+5\delta\theta)))}{4(-1+\gamma)(-1+\delta\theta)(\gamma^3-(-2+\gamma)(4+(-7+\gamma)\gamma)\delta\theta+\delta^2\theta^2)}$.

Appendix 3

Proof for Propositions

Proposition 1: *(Firm 1, Profit Comparison).*

The difference in the optimal profit of firm 1 between the two cases is expressed as

$$\Delta\pi_1 = \pi_1^{T*} - \pi_1^{N*} = \frac{4(1+\eta)(1-q_2)}{(4-q_2)^2} - \frac{1}{4} = \frac{\left(16(1+\eta)(1-q_2)-(4-q_2)^2\right)}{4(4-q_2)^2} = \frac{(16\eta-8(1+2\eta)q_2-q_2{}^2)}{4(4-q_2)^2}$$

Given that $4(4-q_2)^2 > 0$, $\pi_1^{T*} - \pi_1^{N*} \geq 0$ when $16\eta - 8(1+2\eta)q_2 - q_2{}^2 \geq 0$.

$16\eta - 8(1+2\eta)q_2 - q_2{}^2$ is a quadratic function that opens downward with respect to q_2.

Solving for $16\eta - 8(1+2\eta)q_2 - q_2{}^2 = 0$ yields the root $q_2^1 =- 4(1+2\eta) + 4\sqrt{1+5\eta+4\eta^2} > 0$.

The derivatives of q_2^1 are then taken with respect to η. $\frac{\mathrm{d}q_2^1}{\mathrm{d}\eta} > 0$. q_2^1 increases monotonically with η.

When $q_2 \leq q_2^1$, $\pi_1^{T*} - \pi_1^{N*} \geq 0$. When $q_2 > q_2^1$, $\pi_1^{T*} - \pi_1^{N*} < 0$.

Proposition 2: *(Firm 2, Larger Consumer Base, Profit Comparison).*

The difference in the optimal profit of firm 2 between the two cases is expressed as

$$\pi_2^{T*} - \pi_2^{N*} = \frac{q_2(4(1-3\eta) - 4(1-\eta)q_2 - \eta q_2{}^2)}{4(4-q_2)^2}$$

Given that $4(4-q_2)^2 > 0$ and $q_2 > 9$, $\pi_2^{T*} - \pi_2^{N*} < 0$ when $4(1-3\eta) - 4(1-\eta)q_2 - \eta q_2{}^2 < 0$.

Solve for $4(1-3\eta) - 4(1-\eta)q_2 - \eta q_2{}^2 < 0$.

When $\frac{1}{2} < \eta < 1$, $4(1-3\eta) - 4(1-\eta)q_2 - \eta q_2{}^2 < 0$ always holds.

When $\frac{1}{2} < \eta < 1$, $\pi_2^{T*} < \pi_2^{N*}$.

Proposition 3: *(Firm 2, Smaller Consumer Base, Profit Comparison).*

The difference in the optimal profit of firm 2 between the two cases is expressed as

$$\pi_2^{T*} - \pi_2^{N*} = \frac{q_2(4(1-3\eta)-4(1-\eta)q_2-\eta q_2{}^2)}{4(4-q_2)^2},\ 0 < \eta < \frac{1}{2}.$$

Given that $4(4-q_2)^2 > 0$ and $q_2 > 9$, $\pi_2^{T*} - \pi_2^{N*} > 0$ when $4(1-3\eta) - 4(1-\eta)q_2 - \eta q_2{}^2 > 0$.

Solving for $4(1-3\eta) - 4(1-\eta)q_2 - \eta q_2{}^2$ yields the root, $q_2^2 = \frac{-2(1-\eta)+2\sqrt{1-\eta-2\eta^2}}{\eta}$.

The derivatives of q_2^2 are taken with respect to η, $\frac{\mathrm{d}q_2^2}{\mathrm{d}\eta} < 0$. q_2^2 monotonically decreases with η when $0 < \eta < \frac{1}{2}$.

When $\eta > \frac{1}{3}$, $q_2^2 < 0$, that is, q_2^2 lacks any economic meaning.

When $0 < \eta < \frac{1}{3}$, $q_2^2 > 0$.

$4(1-3\eta) - 4(1-\eta)q_2 - \eta q_2{}^2 > 0$ is then solved with respect to q_2.

(1) When $\frac{1}{3} < \eta < \frac{1}{2}$, the root $q_2^2 < 0$ and lacks any economic meaning.

(2) When $0 < \eta < \frac{1}{3}$,

$\pi_2^{T*} \geq \pi_2^{N*}$ when $q_2 \leq q_2^2$. $\pi_2^{T*} < \pi_2^{N*}$ when $q_2 > q_2^2$

Proposition 4: *(Two-Way Cooperation, Threshold)*.

The two-way cooperation requirement is when $q_2 < \min\{q_2^1,\ \ q_2^2\}$.

Let $q_2^1 - q_2^2 =- 4(1+2\eta) + 4\sqrt{1+5\eta+4\eta^2} - \frac{-2(1-\eta)+2\sqrt{1-\eta-2\eta^2}}{\eta}$.

Solve for $-4(1+2\eta) + 4\sqrt{1+5\eta+4\eta^2} - \frac{-2(1-\eta)+2\sqrt{1-\eta-2\eta^2}}{\eta} < 0$.

When $0 < \eta \leq 0.25$, $-4(1+2\eta) + 4\sqrt{1+5\eta+4\eta^2} - \frac{-2(1-\eta)+2\sqrt{1-\eta-2\eta^2}}{\eta} < 0$ always holds.

$q_2^1 - q_2^2 < 0$, the cooperation threshold is when $q_2 < q_2^1$.

When $0.25 < \eta \leq 0.3$, $-4(1+2\eta) + 4\sqrt{1+5\eta+4\eta^2} - \frac{-2(1-\eta)+2\sqrt{1-\eta-2\eta^2}}{\eta} < 0$ does not hold.

When $q_2^1 - q_2^2 > 0$, the cooperation threshold is $q_2 < q_2^2$.

Lemma 1. The function $h(q_2)$ strictly decreases over the interval $q_2 \in (0,1]$. There also exists a unique root $\tilde{q}_2$ such that $h(\tilde{q}_2) = 0$.

$h(q_2) = 16\eta - 4(1+7\eta)q_2 + (-5+4\eta)q_2{}^2 - \eta q_2{}^3$

$h^{'} =- 4(1+7\eta) + 2(-5+4\eta)q_2 - 3\eta q_2{}^2 =- 14 - 28\eta + 8\eta q_2 - 3\eta q_2{}^2$

$h^{''} = 8\eta - 6\eta q_2 = \eta(8-6q_2) > 0$ (Since $0 < q_2 \leq 1$ and $0 < \eta \leq 1$)

h' is derived as a strictly increasing function of q_2.

Therefore, $h'(q_2) < h'(1) =- 14 - 28\eta + 8\eta - 3\eta =- 14 - 23\eta < 0$, which highlights $h(q_2)$ as a strictly decreasing function when $q_2 \leq 1$.

$h(0^+) > h(0) = 16\eta > 0$

$h(1) = 16\eta - 4(1 + 7\eta) + (-5 + 4\eta) - \eta =- 9 - 9\eta < 0$

Given that $h(q_2)$ strictly decreases, $h(0^+) > 0$ and $h(1) < 0$, there exists a unique root $\tilde{q}_2 \in (0,1]$ such that $h(\tilde{q}_2) = 0$.

Proposition 5. *(Two-way Cooperation, Total Profit Comparison).*

$\pi^{T*} - \pi^{N*} = \frac{(16\eta - 4(1+7\eta)q_2 + (-5+4\eta)q_2{}^2 - \eta q_2{}^3)}{4(4-q_2)^2}$.

As $4(4 - q_2)^2 > 0$, $\pi^{T*} > \pi^{N*}$ when the numerator $h(q_2) = 16\eta - 4(1 + 7\eta)q_2 + (-5 + 4\eta)q_2{}^2 - \eta q_2{}^3 > 0$.

$h(q_2) = 16\eta - 4(1 + 7\eta)q_2 + (-5 + 4\eta)q_2{}^2 - \eta q_2{}^3$

$h' =- 4(1 + 7\eta) + 2(-5 + 4\eta)q_2 - 3\eta q_2{}^2 =- 14 - 28\eta + 8\eta q_2 - 3\eta$

$h'' = 8\eta - 6\eta q_2 = \eta(8 - 6q_2) > 0$

$h(0^+) > h(0) = 16\eta > 0$

$h(1) = 16\eta - 4(1 + 7\eta) + (-5 + 4\eta) - \eta =- 9 - 9\eta < 0$

Proposition 6.

(1) *(One-Way Cooperation, Firm 1).*

$\pi_1^{O*} - \pi_1^{N*} = \frac{q_2\left(-8(1+\eta) + \left(-1+8\eta+4\eta^2\right)q_2 - 4\eta^2 q_2^2\right)}{4\left(3q_2 + 4(1+\eta)(1-q_2)\right)^2} + f_2$.

$\pi_1^{O*} - \pi_1^{N*} > 0$ is solved with respect to f_2.

When $f_2 \geq \frac{q_2\left(8(1+\eta) - \left(-1+8\eta+4\eta^2\right)q_2 + 4\eta^2 q_2^2\right)}{4\left(3q_2 + 4(1+\eta)(1-q_2)\right)^2}$, $\pi_1^{O*} > \pi_1^{N*}$, and firm 1 chooses to cooperate.

(2) *(One-Way Cooperation, Firm 2).*

$\pi_2^{O*} - \pi_2^{N*} = \frac{q_2\left(-4(1+\eta) - \left(5+8\eta+4\eta^2\right)q_2 + \eta(3+4\eta)q_2^2\right)}{4\left(3q_2 + 4(1+\eta)(1-q_2)\right)^2}$.

As $\left(3q_2 + 4(1+\eta)(1-q_2)\right)^2 > 0$ and $q_2 > 0$, $\pi_2^{O*} - \pi_2^{N*} > 0$ when $-4(1+\eta) - \left(5 + 8\eta + 4\eta^2\right)q_2 + \eta(3 + 4\eta)q_2^2 > 0$.

However, when $0 < \eta < 1$, $-4(1+\eta) - \left(5 + 8\eta + 4\eta^2\right)q_2 + \eta(3 + 4\eta)q_2^2 < 0$. $\pi_2^{O*} - \pi_2^{N*} < 0$.

Given that firm 2 cannot earn more profit from one-way cooperation than from non-cooperation, this firm 2 refuses to take part in one-way cooperation.

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